SCIENCE

DISCOVERY AND PROGRESS

Adair

Jackson

Carmichael

Urquhart

REVISED FOR CANADIAN SCHOOLS

SCIENCE

Discovery and Progress

DAVIS BURNETT GROSS

Revised for use in Canadian schools

by

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PREFACE

We live in an age of science. Young people, as well as adults, are eager to learn about the biological and physical principles which govern the world in which they live. The authors of SCIENCE believe that the course in general science should give the student an orderly understanding of the materials and forces which make up his environment. The course should also give him firsthand experience with the scientific method used in solving problems, and it should help him adjust his life to the rapid progress which science is making in this Atomic Age.

With these objectives in mind, the authors have chosen the subject matter of SCIENCE with careful regard for those materials which provincial and city syllabi indicate should constitute an ideal curriculum in general science. Realizing that the nature and extent of the science taught in the elementary grades vary from school to school, and even within school systems, the authors have met this wide variation in student needs by providing in the twenty units of this textbook a complete program covering the major areas of science. Allowing for the usual curriculum sequence, major emphasis is based on the physical sciences because few students will take further work in physics or chemistry. The biological areas are well represented by discussions of basic principles and applications which serve as a stepping stone for the many students whose high school courses will include a full year of biology.

The content has been tested in the authors' own classrooms many times and under various conditions, and the reactions of students to it have been taken into consideration in revising each unit. This classroom testing has indicated that students want to know the *what,* the *how,* and the *why* of scientific phenomena. Descriptive materials in the text, actual demonstrations by the instructor, and activities which the student performs himself help him learn *what* happens and *how* it happens, but an answer to the *why* will come only from explanation, reasoning and interpretation. Great care has been given to the development of a logical sequence leading to the inductive discovery by the student of each scientific principle and its application.

All the twenty units are organized around a large problem based on a special division of subject matter. This large problem is then subdivided into smaller assignment sections lettered A, B, C, etc. Each topic in these sections is a learning problem, complete with its own questions. Insofar as the nature of the subject permits, the sections are arranged in order of difficulty, thereby providing a practical plan

for differentiation. The development of each topic is concise and direct. Wherever possible, the central ideas are unmistakably emphasized as topic sentences. A consistent pattern is followed in developing the *what,* the *how* and the thinking to arrive at the *why,* exactly as a scientist would do. Thus, the scientific method is constantly used by the student and he begins to think objectively and to learn the art of logical reasoning.

Each unit begins with *Discovery and Progress,* which describes some of the major scientific discoveries or inventions. These are shown in line drawings on the facing page and illustrate pictorially what the text describes in words. This historical approach has proved to be highly successful as a motivating device because the student can see the steps by which science has improved man's life in past years as well as in modern times.

The *Questions to Direct the Study of This Unit* introduce the problems to be investigated and consist of actual questions which the authors' students have asked in the classroom. Each is answered completely in some part of the text of that unit. Following these questions is a list of *Words to Help You Understand This Unit,* comprising the important new scientific words and terms which appear in the text. They are defined and pronounced phonetically so the list may be used as a unit glossary if the instructor so desires. Each of these, and all additional words and terms, are again defined and pronounced in the complete Glossary in the back of the book. In the text proper each new word is printed in ***boldfaced italics*** the first time it is used and is defined and pronounced there. The authors do not believe in using words which are not actually necessary in teaching a scientific principle. However, they have included those new words or terms as are really needed to describe the phenomena. Such emphasis and drill on a scientific vocabulary make the language of science easy for the student and enable him to comprehend its principles and applications better.

Each lettered section of the unit comprises approximately one assignment and includes text material, demonstrations, and activities. The demonstration usually involves some form of laboratory apparatus, none of it elaborate or expensive, and is designed to be performed either by the instructor alone or by a selected small group of students who will work under his direct supervision and guidance. The activities are comparatively simple, involving either homemade or unbreakable apparatus and may be performed quite safely by any student or group of students. The section ends with a group of short, factual review questions which test the student's ability to understand the material which he has just studied.

The materials at the end of each unit have been carefully prepared to evaluate retention, comprehension, and the ability to use knowledge intelligently. *Questions for Review and Discussion* were written to stimulate the student to think over and to organize the fundamental principles and applications of each problem. They also serve as the basis for further discussion of the topic. There follows a group of topics for special reports, some of which may be done in the library, while others pertain to manual activity and require the student to make something with his hands. *Testing the Purposes of This Unit* is concerned with the general and specific features of the scientific point of view. It should help the student understand the social implications of the problems which scientific discoveries have created. The unit closes

with *The Old and the New,* a simple narrative comparing what science has done in the past with present progress and pointing out some of the possibilities that lie ahead. The student will undoubtedly want to add ideas and suggestions of his own to this comparison.

The illustrations in SCIENCE have been meticulously planned. Each demonstration and most of the activities are illustrated by a line drawing, many employing color as a help to learning and to enable the student to understand visually what he has read. Thus, the demonstrations or activities are a great aid to learning whether or not there is available apparatus to perform them. Any teacher knows that diagrams and drawings will often clarify a principle more vividly than endless words. The many superior drawings in SCIENCE were prepared to do precisely this. Photographs are also used effectively throughout the book to show the magnitude and actual appearance of many practical applications of scientific principles.

In preparing the manuscript for SCIENCE the authors have kept in mind the fact that a good textbook must be written in such a way that it can be understood by *all* students. Accordingly, they have used short sentences and monosyllabic words as often as possible. The text is personalized to a high degree and the frequent use of the pronouns "we" and "you" makes for easier reading. The various readability formulae have been carefully studied and the text is geared to approximately the eighth-grade level. Using a simple, direct style, the authors have written for the student and never "talk down" to him.

Finally, the authors wish to express their deep appreciation to each of the following teachers who have read part of the manuscript and have offered many helpful suggestions: Dr. Russell Meinhold, Chairman of the Division of Science and Mathematics, Rhode Island State College of Education, Providence; Mr. Paul Bauer, Instructor in Physics and General Science, Hughes High School, Cincinnati, Ohio; and Mr. Joseph F. Castka, Chairman of the Science Department, Martin Van Buren High School, Queens Village, Long Island, New York.

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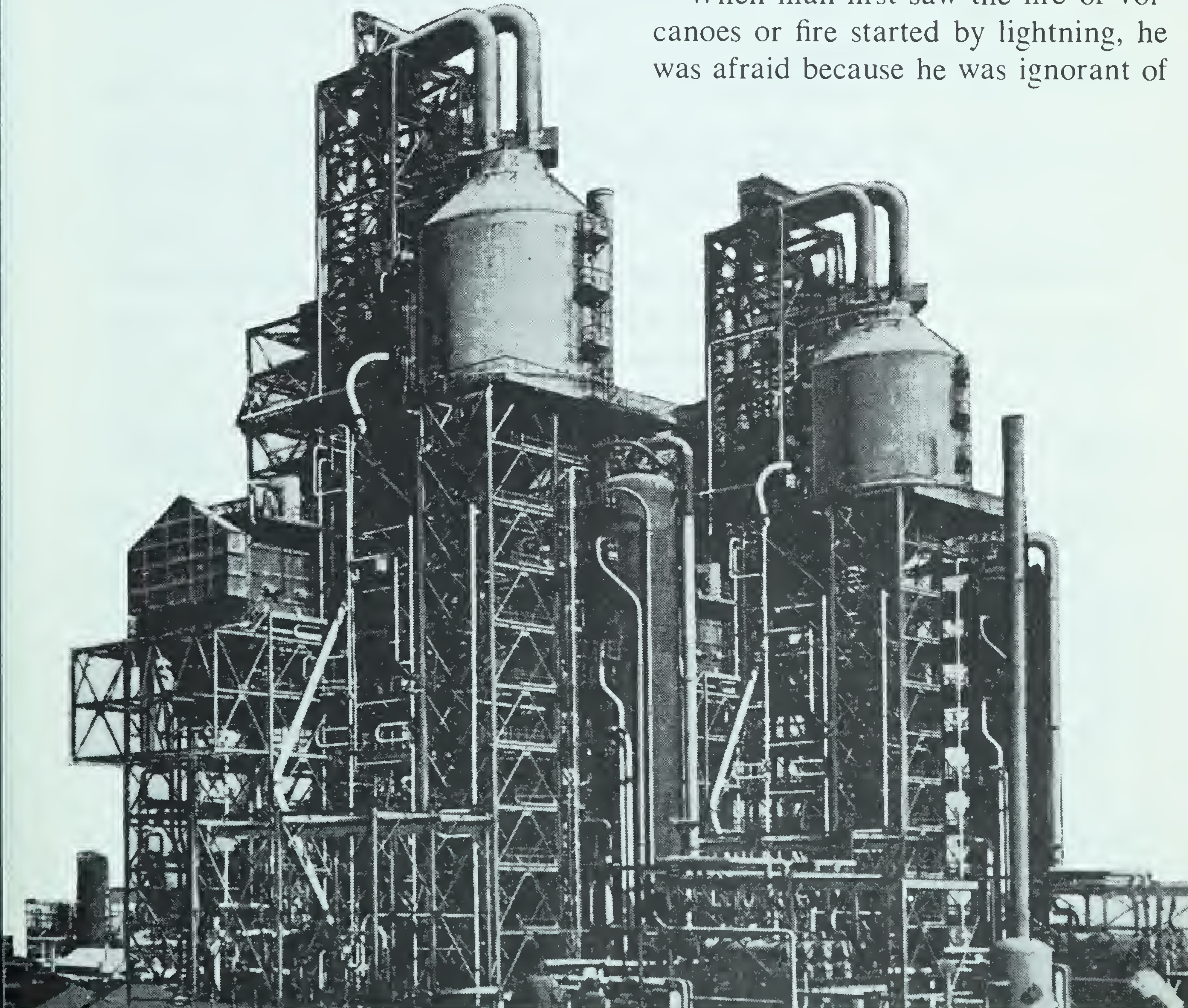
UNIT 1

How has man learned to use the materials and forces of nature?

DISCOVERY AND PROGRESS

TODAY science has become the most important single field of human knowledge. It has helped man to change and to control both his physical and social environment. These surroundings in which we live make up our environment. All living things, plants, animals, and man, must adapt themselves to their environment, or they may not survive.

When man first saw the fire of volcanoes or fire started by lightning, he was afraid because he was ignorant of



the causes. Later, he learned that he could use fire to keep him warm, to cook his food, and to shape metals. Thus, man began to lead a more civilized life. Today, in addition to heating and cooking, man uses fire to drive machines, to keep industries running, and to generate electricity.

The availability of food is one of man's first requisites of his environment. With modern scientific methods, he is able to have a steady supply of food the year round. He has learned to use the soil wisely for growing crops and to raise animals so that he can obtain the greatest benefits from them.

He has learned also to control and use wisely one of his greatest natural resources—water. Where water is not available, he digs irrigation ditches so that he can obtain water for his crops. Floods have been and still are, though to a lesser extent, a problem that the modern scientist is trying to control. The building of dams and wise conservation practices have been a big factor in their prevention. With these controls in certain regions, it is possible to keep the rich topsoil from being washed away and to protect homes and property from disastrous floods. Oil, another natural resource, provides us with one of our principal sources of fuel. The photograph on page 1 shows a pipe still that is used in refining petroleum.

At one time, man was forced to live only in the climates to which he could adapt himself. Today, however, with heating and air-conditioning systems, man can control his environment. The use of clothing and shelters are also factors that make man independent of his surroundings. Thus, he is able to move from place to place.

With modern means of transportation—by land, water, and air—great distances can be overcome. Railroads, automobiles, ships, and airplanes are the products of scientific experimentation.

Hand in hand with means of transportation are the effective ways of communication with people of far-distant lands. Today, with telephones, telegraphs, radios, and television, people can learn more about social, economic, and scientific developments in all parts of the world.

Think of the many ways natural forces have shaped human destiny and events. Atomic energy is being used more and more in medicine, industry, and transportation. At one time, work could be done only during daylight hours. Today, because of electricity, production can continue around the clock. This means more food, more clothing, and greater production of all the necessities of life. Thus, the standards of living can be raised to a higher level.

Through man's increased knowledge of medicine and his body, he is able to live a longer, healthier, and more comfortable life. By discovering the causes of disease and by progress in the methods of controlling them, people are able to live in what were once uninhabitable regions.

The more scientific knowledge a person has, the more he is able to use the materials and forces of nature to his best advantage. As you learn more about science, you can apply this knowledge to your everyday living.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What is your environment? **2.** What is matter? **3.** How is one form of matter different from another? **4.** Does air take up space? **5.** Does air have weight? **6.** What is gravity? **7.** Why do you fall over if you turn a corner too sharply on your bicycle? **8.** What is energy? **9.** Are heat, light, and electricity matter or energy? **10.** What is the source of the energy in an atomic bomb? **11.** How can you solve a scientific problem? **12.** What are the characteristics of a person who has a scientific attitude? **13.** How do superstitions originate? **14.** How reliable are superstitious beliefs? **15.** What is nuclear energy?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

atom	the smallest particle of any element that has the properties of that element.
element	one of the basic substances which cannot easily be broken down into other substances.
energy	the ability to do work.
environment . .	(en-*vy*-run-ment), the things around you and the forces acting on you; your surroundings.
friction	the resistance to motion when any materials rub against each other.
gravity	a force of attraction which pulls bodies toward the center of the earth.
force	a push or pull which tends to produce or prevent motion.
inertia	(in-*er*-shuh), the tendency of a body at rest to remain at rest, or of a body in motion to remain in motion with uniform speed in a straight line (other forces can change the direction).
inorganic	pertaining to nonliving matter.
kinetic energy .	(kin-*et*-ick), energy of motion.
matter	anything which occupies space and has weight.
organic	pertaining to living matter, or matter that was once living.
potential energy	(poh-*ten*-shal), energy that is stored up.
science	classified knowledge gained by observation and experimentation.

A What are the materials and forces of nature in our environment?

The things around you and the forces which act on you make up your environment. All living things, including man, are dependent on each other and on the materials and forces of nature. Plants can take materials from the air, water, and soil, and make food for themselves and for other living things. The sun provides the necessary heat and light for this work of food-making. Thus the heavenly bodies, climate, heat, soil, light, air, and water are part of our environment. They help to determine where and how living things can grow and maintain themselves.

Science includes the study of these materials and forces in our environment, and our relation to them. *Science* is classified knowledge gained from observation and experimenting, as we shall see throughout our course in science.

In your environment, all things are forms of matter. *Matter* is anything that occupies space and has weight. Air, water, soil, plants, animals, man, and the heavenly bodies are all forms of matter. Your environment also includes forces which make life possible by enabling you to use the different forms of matter. *Energy* is the ability to do work. But the true nature of matter and energy is still not entirely understood. So we can study them better by the properties they *have,* rather than by what they *are.*

We recognize matter by its general and special properties. Despite their differences, all forms of matter have the following properties: (1) all matter has weight; (2) all matter occupies space; (3) matter cannot easily be destroyed; and (4) two portions of matter cannot occupy the same space at the same time. We call these characteristics *general properties of matter.* But they do not distinguish one form of matter from another.

On the other hand, *special properties of matter* help us to distinguish one form from another. For example, we say that some glass is brittle and transparent. We know that sugar is sweet, that gold has a yellowish color, that rubber is elastic, that lead is heavy, and that iron is hard. What *special* property might help you to recognize each of the following: copper, brass, silver, wood, salt, diamonds?

Matter includes both living and nonliving materials. The scientist classifies matter as organic and inorganic. *Organic matter* is alive or comes from living things. *Inorganic matter* has never been alive and is always nonliving. Chemists have a more technical meaning for the word organic. Try to find this specialized meaning and compare it with the more general meaning used here.

Organic matter includes all *animal life and plant life.* In your environment, you see many different forms of animal life. They vary from the tiny

Fig. 1-1. In this photograph, identify both forms of matter, organic and inorganic.

creatures, which you can see only with a microscope, to the giant whale and elephant. Plants also vary in size from tiny bacteria to the giant Douglas firs which grow to such heights on our West Coast.

Sometimes it is hard to distinguish between organic and inorganic matter. Wood and leather are called *organic* because they are plant and animal products. Iron, tin, and air are called *inorganic* because they have never been alive. They are not products of living things. But coal, which looks like inorganic rock, is actually organic because it was formed millions of years ago from living trees and plants.

One difference between organic and inorganic matter is that most organic matter will burn or char easily. This is because organic substances contain carbon. Most inorganic substances will not burn at ordinary temperatures although a few, like sulfur and phosphorus, burn readily. However, these do not char like organic substances.

DEMONSTRATION

Try burning various materials, such as paper, wood, water, leather, rock, glass, iron, sugar, and bread. Which substances are organic? Which are inorganic? Name five other organic substances in your environment; five inorganic substances.

Energy is constantly in use in our environment. Although scientists do not yet know what energy *is,* they do know many of the things it *does.* In terms of its effects, we may think of energy as the ability to push or pull or cause motion. It drives trains, propels boats, and lifts heavy weights. It also heats our homes, cooks our food, and brings us radio and television.

The sun is the original source of most of our energy. Sunlight enables plants to use air, water, and soil to make food. We eat this food, and it gives us energy. We shall see later how the scientist has learned about the different forms of energy and how one form may be changed to another.

REVIEW QUESTIONS

1. What is your environment? **2.** What things in your environment are classed as matter? **3.** What is the difference between organic and inorganic matter? **4.** What properties are common to all matter? **5.** Name five special properties of matter. **6.** What things in your environment have energy? **7.** How do you use energy in your environment?

B What properties of matter make it useful to man?

Matter exists in the form of solids, liquids, and gases. Each form has its own special properties. These help us to tell the three forms apart. *Solids* usually have a definite size and a definite shape. *Liquids* have a definite size or volume, but their shape depends on the shape of the container into which they are poured. *Gases* have neither a definite shape nor a definite volume. A given amount of gas will fill any container regardless of the size or shape of the container. In fact, we must enclose the gas to keep it in a container.

Many kinds of matter can be converted from one form to another by changes in temperature. If a liquid, such as water, is cooled enough, it changes to a solid, ice. If it is heated sufficiently, it will change into an in-

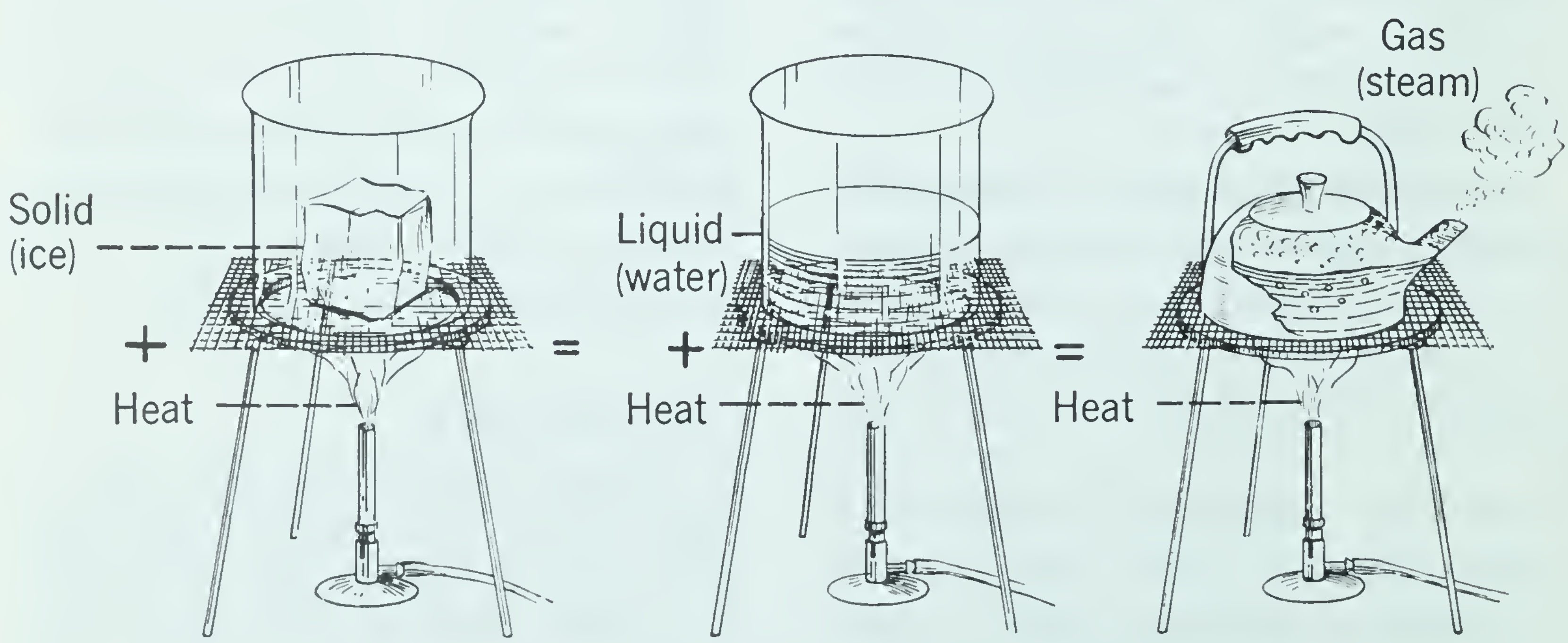


Fig. 1-2. Matter can be changed from one form to another.

visible vapor or gas called ***water vapor*** or ***steam*** (see Fig 1-2). Air, which consists of several different gases, may be cooled sufficiently to change it into a liquid. Intense heat will change solid rock to a liquid. Further heating may change the liquid rock into gas.

PUPIL ACTIVITY

Fill a beaker one-third full of water. Put the beaker on a support stand and heat it over a burner. When the water in the beaker boils, lower a cool beaker, with the open end down, over the heated beaker (see Fig. 1-3). What happened? Describe the changes you saw. What caused these changes?

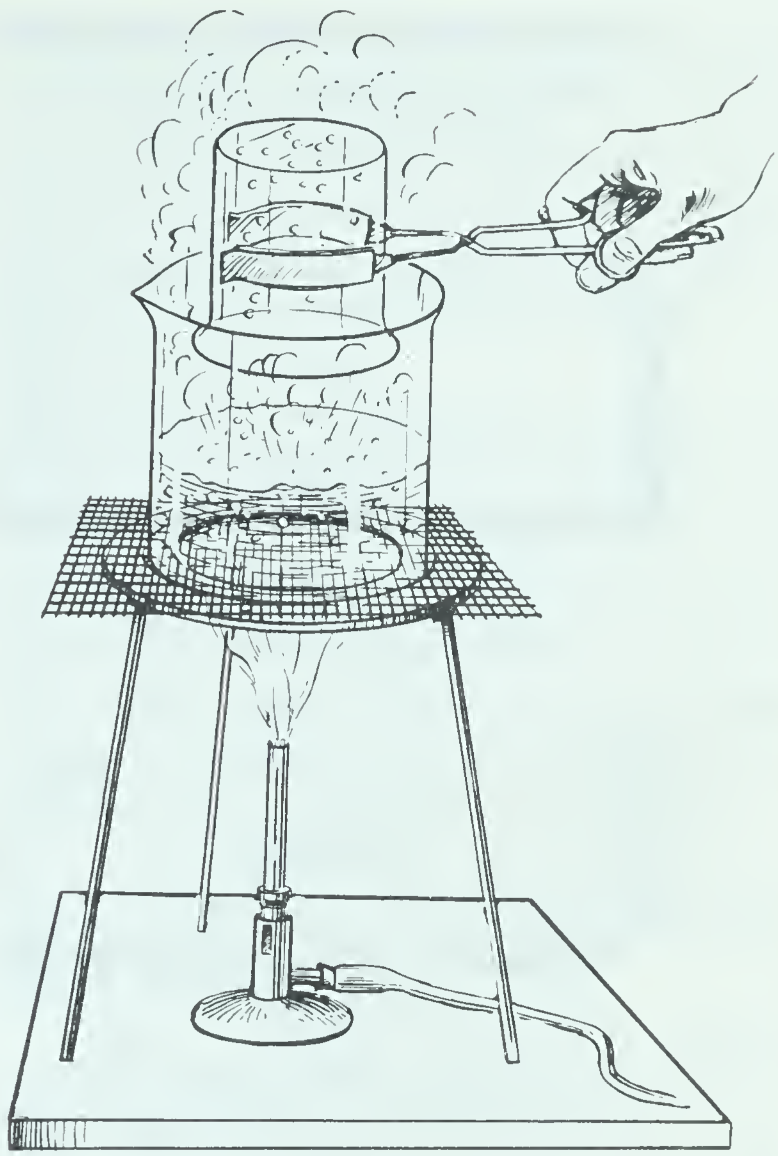


Fig. 1-3. From this diagram, you can see how changes in temperature may cause water to change its form.

All matter occupies space. The word "space" has several meanings. You have probably used it to mean length or distance. If you use the expression, "the space between two buildings," space means ***distance.*** If you calculate the floor space in a room, space means *area.*

Area is usually the product of the two dimensions, *length* and *width.* When we say matter occupies space, space means *volume.* ***Volume*** is usually the product of the three dimensions, *length, width,* and *thickness.*

In this country we use what is called the ***English system*** of weights and measures. The units of weight are *ounces* and *pounds.* Units of linear measure include *inches, feet* and *yards.* These are familiar, having been brought in, in modified form, from England after 1759.

A more scientific system of measurement is the ***metric system.*** It is used in most European countries and by scientists the world over. In this system the unit of weight is the *gram,* and the unit of linear measure is the *meter*. Its chief advantage is that it is a *decimal* system, just like our system of dollars and cents. Thus a meter is divided into 100 *centimeters,* and a *kilogram* is 1000 grams.

The metric system is being more widely used every day. The weight of canned goods is often given on the label in grams as well as in pounds and ounces. An artillery piece is called a 75 millimeter gun instead of a 3-inch gun (a *millimeter* is one one-thousandth of a meter). Liquid drugs are measured in cubic centimeters (a *cen-*

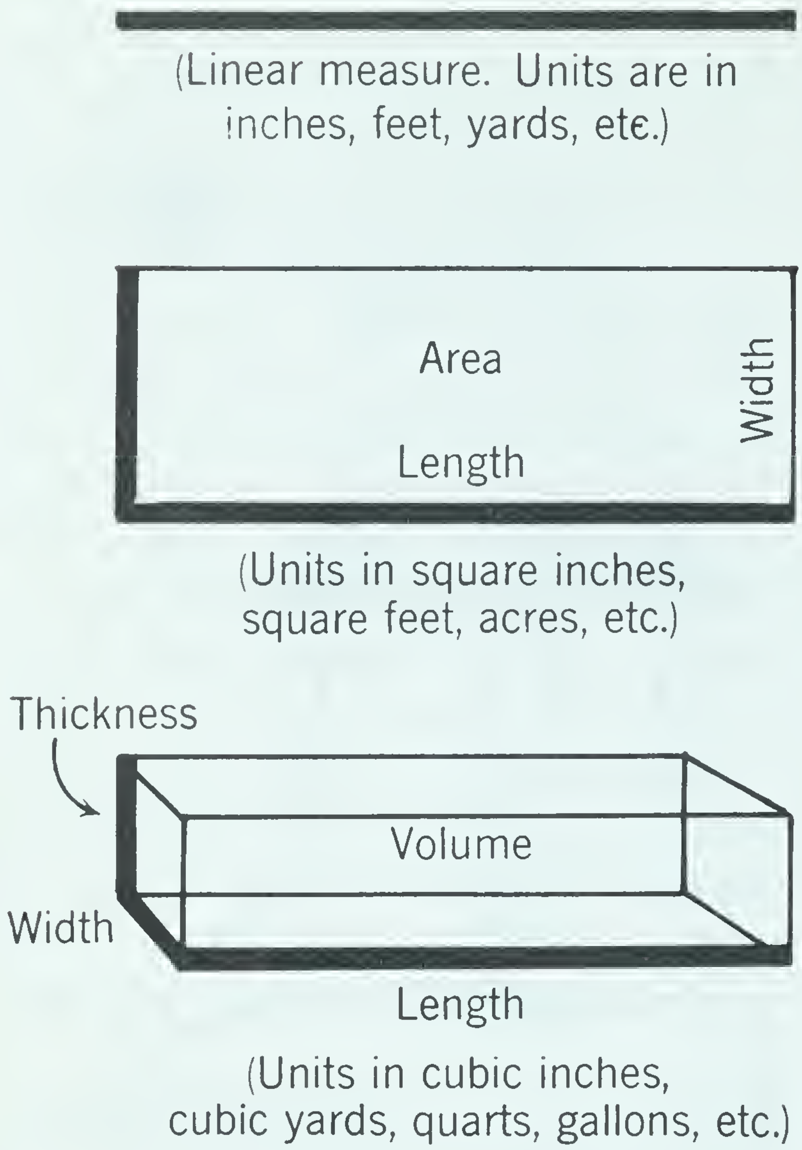


Fig. 1-4. You can measure length, area, and volume with a yardstick or meter stick.

timeter is one one-hundredth of a meter). Distances in the Olympic Games are measured in meters, while in our track meets we use feet and yards.

Experimental methods that we shall use in this book. To help you in your study of science, we include in this book two types of experiments. One type is marked PUPIL ACTIVITY. Such activities help you to learn how to use the tools of science. They also give you practice in solving problems and answering questions that may come up in class.

Some of these activities can be performed by all the students in the class. If the supply of equipment is limited, you may have to work in groups. In other cases, a small group of students may perform the activity for the whole class.

The other type of activity is marked DEMONSTRATION. Demonstrations will be done in class, either by the teacher or by a few students. Sometimes the teacher will require student assistants.

In each demonstration observe what equipment is used. Notice what happens in each part of the demonstration and record the results. You should be able to come to some conclusion after each demonstration.

PUPIL ACTIVITY

Measure the length of the cover of this textbook. Give the length in inches and parts of an inch. Also measure the width of the cover. What is the area of the upper surface of the cover? The area is equal to the product of the length and width.

Next, measure the thickness of the book. What is the volume of the book? The volume is the product of the length,

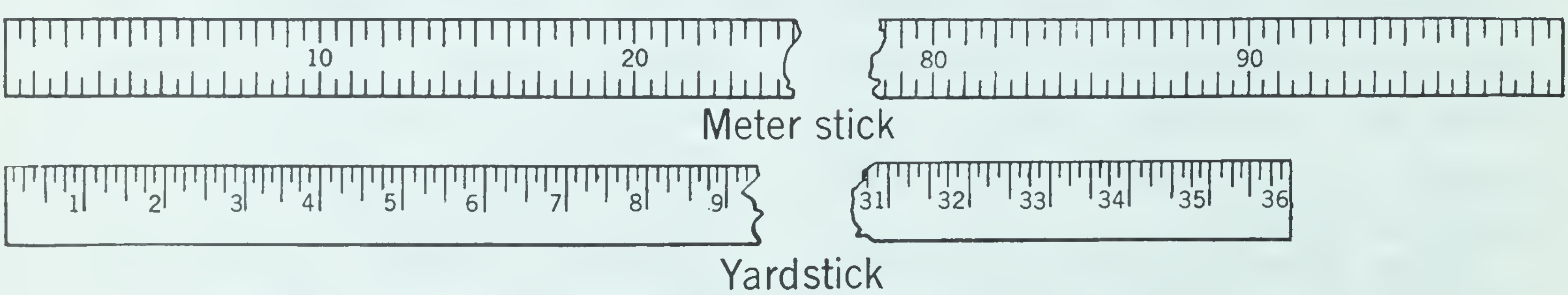


Fig. 1-5. As you can see above, a meter is a little longer than a yard.

width, and thickness. Repeat this exercise, using the metric system of measurement. Compare your measurements and results with those of the other pupils in the class.

Air occupies space and has weight just as any other form of matter does. You have heard of an empty can and an empty room. But the empty can and room are filled with air. If water is poured into a container of some kind, air must be allowed to escape. We can easily see that air occupies space, as shown in Fig. 1-6.

PUPIL ACTIVITY

Fill a jar about two-thirds full of water. Then lower a test tube, open end down, into the water. Does the water enter the test tube? Why? Repeat the experiment using a tumbler in place of the test tube. What is the result? Why? Tip the tumbler and explain the result.

DEMONSTRATION

Put the stem of a funnel through one of the holes of a two-hole rubber stopper. Put a glass tube in the other hole. Fit the rubber stopper tightly into a bottle. Close the tube by putting your finger over the end of it. Fill the funnel with water. Does the water enter the bottle? Remove your finger. Does the water enter the bottle?

Water did not enter the tumbler or bottle until some of the air had escaped. The water and air could not occupy the same space at the same time. The same thing would be true if the bottle were filled with oil. The water could not enter the bottle unless the oil was pushed out. If the bottle were filled with small pebbles, water would enter to fill the space between the pebbles.

Matter is pulled toward the center of the earth by the force of gravity. You may remember that when you were very young, you fell down frequently. You also learned early in life that any object thrown into the air fell back to the ground. These effects are caused by gravity.

But what is gravity? *Gravity* is the

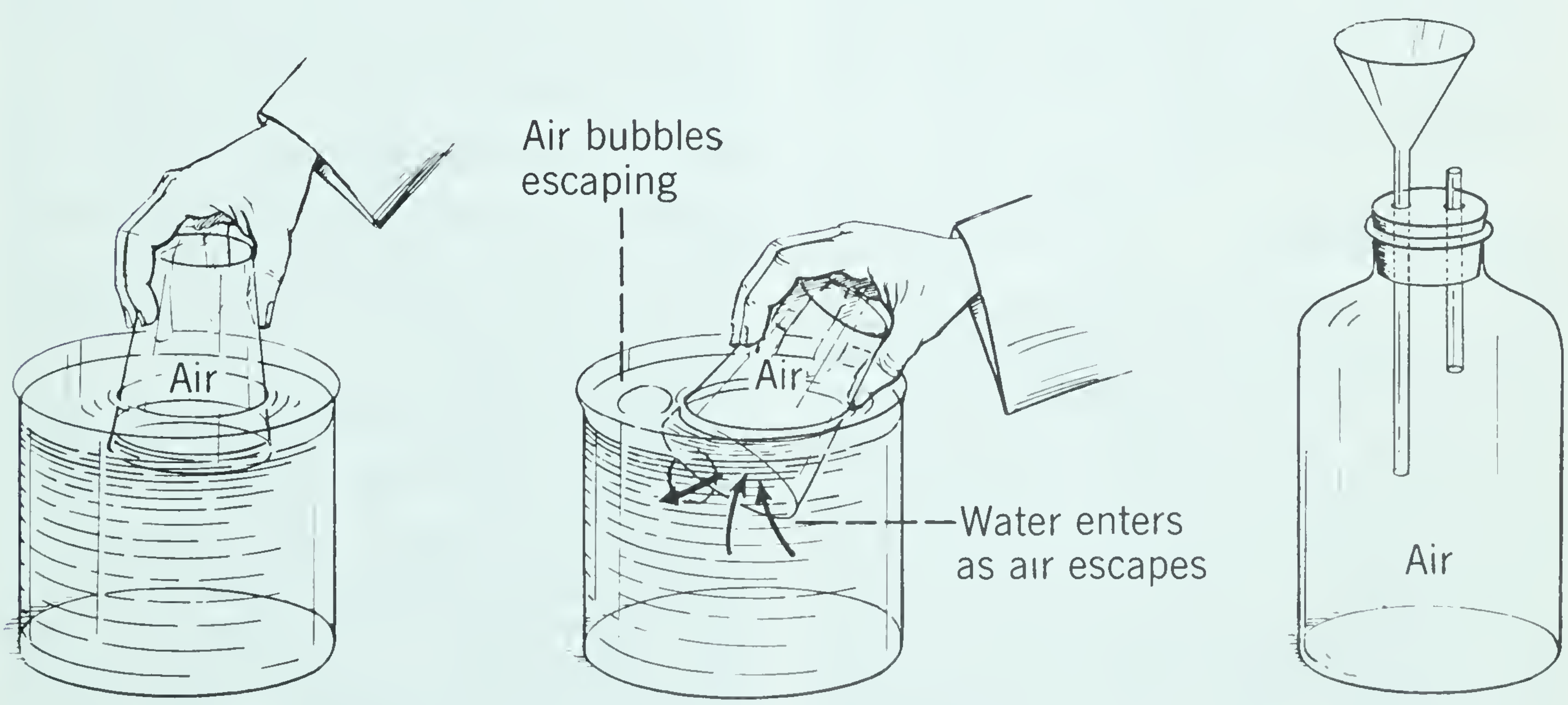


Fig. 1-6. Air occupies space. In this respect, it is like all other forms of matter.

force of attraction which pulls bodies toward the earth. When you throw a ball into the air, it falls to the ground because the earth's force of gravity attracts it. Gravity causes water to run over a dam or down a hill. By its force of attraction, gravity draws water closer to the center of the earth.

A *force* is a push, a pull, or a lift which acts on all forms of matter, tending to move them or to change their position or form. Thus, gravity is a force because it tends to move all forms of matter toward the earth's center.

Gravity is one example of a force that acts throughout the universe. You should know by now what we mean by gravity. The word ***gravitation*** is used for the force that draws all bodies in the universe toward each other. The earth and all the heavenly bodies attract each other. The sun's gravitation holds the planets in their paths around the sun. The earth's gravitation holds the moon as it revolves. Later we shall see how gravitation causes tides by the conflicting attractions of the sun, moon, and earth upon the water in our oceans.

PUPIL ACTIVITY

First, let a small block of wood and a sheet of typewriter paper fall *at the same time* from the *same height* to the floor. Because of the resistance of air on the paper, the block of wood will reach the floor first. Now crush the paper into as small a ball as possible. Again let the wood and paper fall at the same time the same distance. Do they both reach the floor at about the same time?

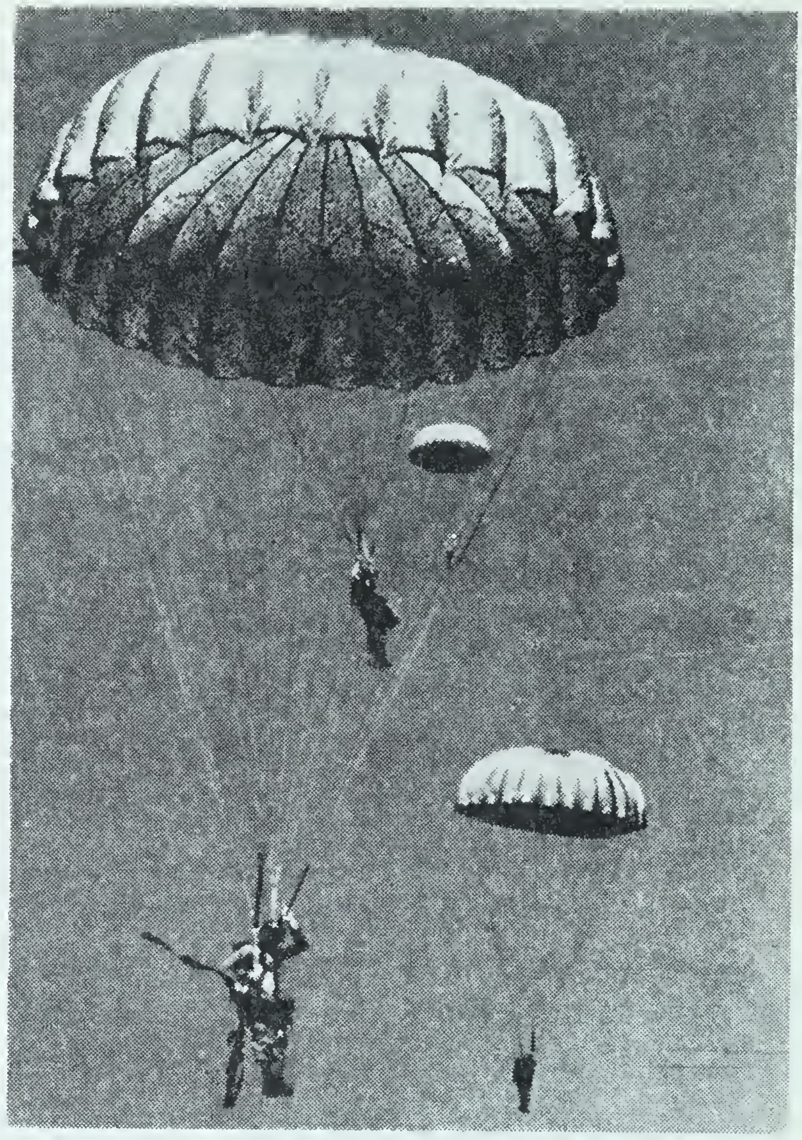


Fig. 1-7. The force of gravity causes these paratroopers to fall toward the earth.

This shows that paper and wood fall at the same rate of speed if we neglect the resistance of air. If you repeat this experiment many times, using different objects, you can draw this conclusion: *all objects fall with the same speed from the same height.* Or, to put it scientifically, the force of gravity pulls all objects to the earth with the same speed, if air resistance is disregarded, and if they fall from the same height.

This experiment shows how a belief may be wrong even though it seems reasonable. Before the experiment, most of you probably would have said that the block of wood would fall faster than the paper. That answer seemed reasonable but it was not cor-

rect. The experiment is important because it proves that you can best find correct answers *only by careful experiments and observations* which you or others have made.

All matter has weight. Weight is the measure of the earth's force of gravity on an object. When you say you weigh 125 pounds, it means that the earth is pulling on you with a force of 125 pounds. If you learn that a book weighs two pounds, it means that the earth is pulling on the book with a force of two pounds.

Man has invented an instrument called a balance to measure the pull of the earth on an object. The ***balance*** compares a known weight on one arm with the unknown weight you are trying to measure on the other arm. The government establishes weight standards by law; for example, pounds, ounces, tons.

In order to make the balance more useful, we use a set of standard weights. Scientists frequently use the ***gram*** as a unit of weight. A pound is equal to approximately 454 grams.

The total of the weights you use on the right-hand pan of the balance (see Fig. 1-8), plus the reading on the slider arm of the balance, is equal to the weight of the object. This total weight is the pull which the earth's force of gravity is exerting on the material on the left side of the balance.

The foot rule was one of the first pieces of scientific apparatus. The balance is the second important measuring device. It can measure your weight, and that of any object you buy. Many materials formerly sold by the dozen or by bulk (volume) are now sold by weight. For example, corn is now sold by weight rather than volume. Weight is an accurate measurement and is used for many items in the solid state. However, liquids and gases are usually sold by the gallon or the cubic foot because it is more convenient.

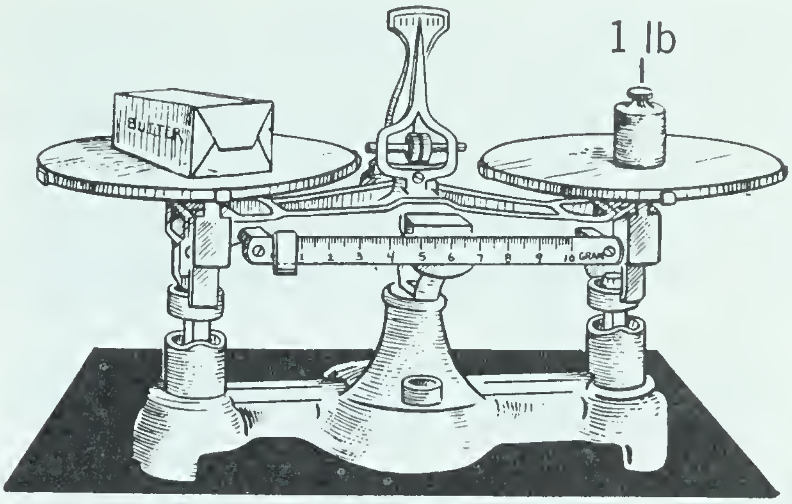


Fig. 1-8. A balance determines the exact weight of an object.

PUPIL ACTIVITY

Clean the pans on the balance. Set the slider weight at the zero mark or at the left end of the bar. Adjust the screw so the pointer will be at the zero or central mark. Now put some object on the scale pan at your left. Add weights on the scale pan at the right until the pointer is near the zero mark. Then use the slider weight to bring the pointer to the zero mark. The pull of gravity on the weights is now equal to the pull of gravity on the object. The sum of the weights on the right scale pan and the weight on the slider arm is the weight of the object.

What is the weight of the object? With what force does gravity pull on the object?

Weigh a pint bottle. Now fill it with water and weigh it again. What is the weight of the water in the bottle? A pint of water weighs about one pound. Check

the accuracy of the weight of something sold by the pound. If you have a scale at home, check the weight of some articles that you have recently bought at the grocery store. Compare your weighing with the weight marked on the packages.

You can show that air has weight. You have learned that air is a form of matter. This means that air not only occupies space, but also has weight. Twelve cubic feet of air like that in your classroom weigh about one pound.

DEMONSTRATION

Weigh a football or volley ball when it is inflated. Now let the air escape from the ball. Weigh it again after the air has escaped. Has the weight changed? Conclusion? From your results calculate what volume the air in the ball would occupy when it escaped into the room.

REVIEW QUESTIONS

1. In what three forms does matter exist? **2.** Give two examples of each form of matter. **3.** What is the surface area of a board ten inches long and eight inches wide? **4.** How many cubic feet of water would it take to fill a tank four feet long, three feet wide, and two feet deep? **5.** What Pupil Activity proved that air occupies space? **6.** What force attracts matter to the earth? **7.** What is weight? **8.** How do we weigh air? **9.** Why are the ruler and the balance such important pieces of apparatus? **10.** What is the weight of air in a room 24 feet by 30 feet by 12 feet in dimensions if a cubic foot of air weights $\frac{1}{12}$ of a pound? **11.** What is the approximate weight of a quart of water? **12.** Name three items that are sold by linear measure, three by area, and three by volume.

C How has man learned to use inertia?

Matter, if at rest, remains at rest; if in motion, it stays in motion unless acted on by some other outside force. If you put an object in any particular place, it will stay there unless you apply some other force to it. An object stays where you put it and will not move to another position unless you start it moving. Therefore, we say that nonliving matter cannot move itself.

But if you set an object in motion, it will continue to move in the same direction. An object in motion would continue to move forever if friction and the force of gravity did not so stop it. *Friction* is the resistance to motion which occurs when materials rub against each other. We use the word *inertia* (in-*er*-shuh) to express the tendency of matter to remain at rest, or to continue in motion with uniform speed in a straight line.

DEMONSTRATION

Attach a spring balance to a loop of string tied around a brick or block of wood, as in Fig. 1-9. What force do you need to start the brick moving? What force do you need to keep the brick moving at a uniform speed? Why is one force greater than the other?

To move the brick you had to overcome both friction and the force of

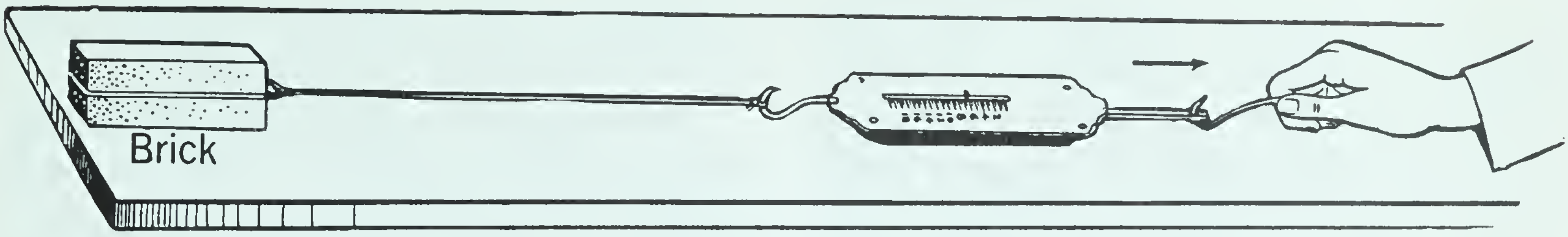


Fig. 1-9. What two forces must be overcome in moving the brick?

inertia. But when it was moving, all you had to do was to overcome friction. That is why it took a greater force to start the brick moving than it did to keep it moving at a uniform speed.

PUPIL ACTIVITY

Put a piece of cardboard over the mouth of a bottle. Then put a small coin on the cardboard directly above the center of the bottle. Quickly snap the card sideways off the bottle with your finger. What happens to the coin on the cardboard? Why?

When you snapped the card quickly, it moved away so rapidly that inertia kept the coin where it was until gravity acted on it.

You have probably seen the trick of suddenly pulling a tablecloth from a table without disturbing the table setting. This is possible because of the inertia of the objects on the cloth. When playing games, children learn by experience to overcome inertia. How does a hundred-yard-dash man get a quick start? Why is it hard to catch a baseball thrown very fast? You need force to overcome the inertia of any object, whether it is at rest or in motion. Inertia is a property of all forms of matter.

You can move objects through water because of its inertia. In swimming

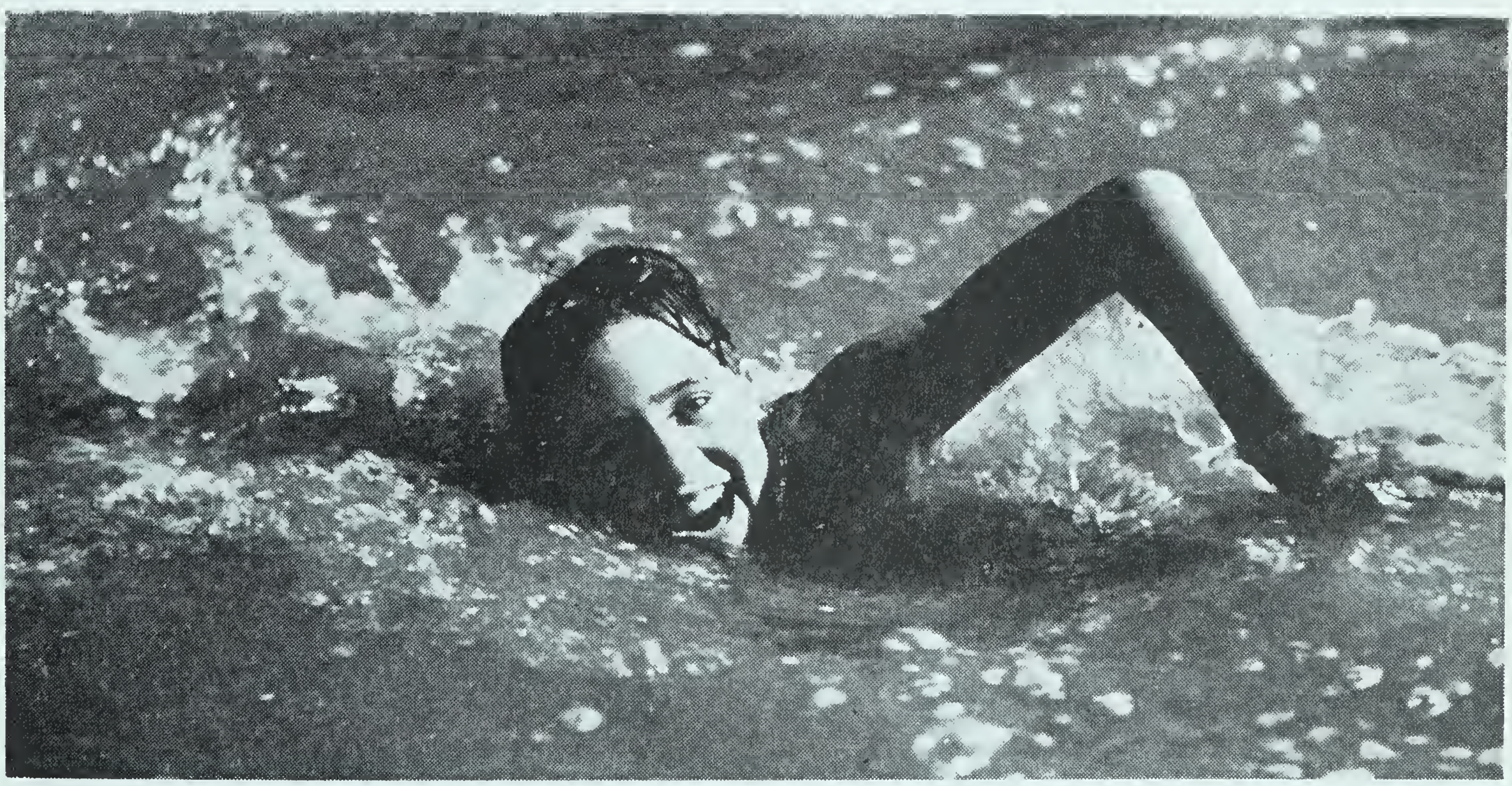


Fig. 1-10. How can this swimmer take advantage of inertia of the water to push himself forward?

you make use of inertia of the water by pushing rapidly against it with your arms and legs. If you move your arms and legs slowly, there is time for the inertia to be overcome. Thus, the water would be pushed back slowly and you would make little forward progress. But if you exert a force quickly, the inertia of the water will push you forward. If you apply the force downward, inertia will cause you to move upward. Boats and ships move through the water by rapid motion of oars or propellers which push against the water fast enough to take advantage of its inerita.

Air also has inertia. We have all felt the force of wind. In tornadoes and hurricanes, winds cause tremendous damage. This is because moving air tends to stay in motion and so exerts force on anything in its path.

An airplane moves through the air because the propeller exerts a force against the air. The air at rest exerts a force against the rapidly moving propeller. This pushes the plane forward.

DEMONSTRATION

Get a *thin* strip of wood about five inches wide and about eighteen inches long. Put it on the table so that about five inches of its length project over the table top. Spread a double thickness of newspaper over the board and on the table. Push down on the projecting end of the board gently. Result? Smooth the paper down snugly again, and strike the projecting edge of the board a hard blow with a large board or baseball bat. Result?

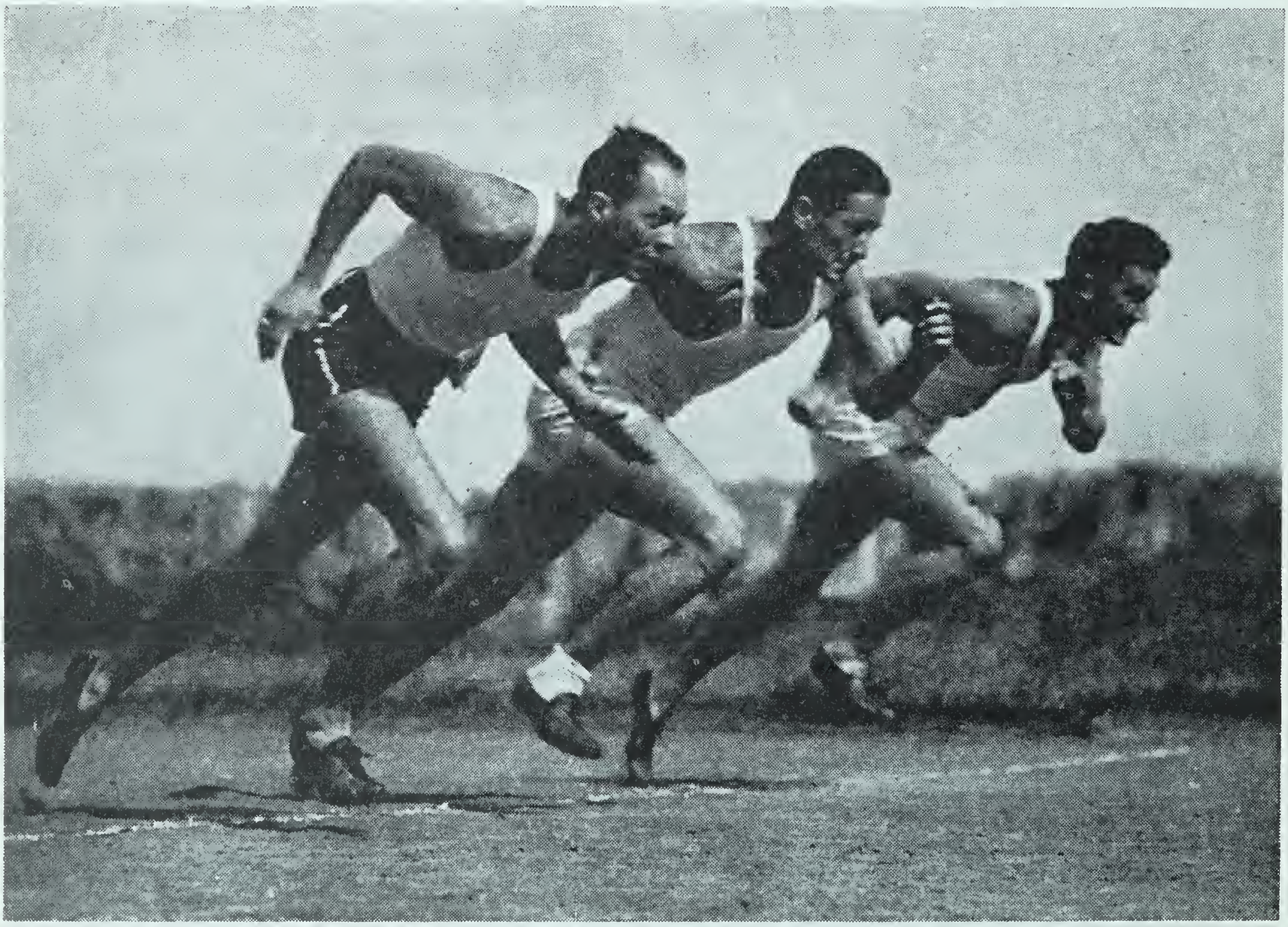


Fig. 1-11. Trackmen have to overcome inertia in order to get a good start.

If you push slowly on the board, there is time to move the air above the paper and also for air to flow under it. If you exert the force quickly as in pounding, then you are really trying to move all the air above the paper. The board breaks because the force needed to move the air is greater than the force needed to break the board. It takes a large force to overcome the inertia of this weight of air.

PUPIL ACTIVITY

Wind a string around the shaft of a small gyroscope. Pull the string quickly. Result? Balance the spinning gyroscope on the end of your finger or on a pencil point. Result? Why does a spinning gyroscope behave in this way? Try to find some practical uses for a gyroscope.

Here are several common forms of inertia. In riding a bicycle you push on the pedals to start the bicycle moving. You do this to exert a force which will overcome the inertia of the bicycle. Once it is moving, you can coast a while because of inertia. However, unless you exert more force, gravity and friction will stop the bicycle. In shoveling dirt, you swing the shovel forward. Both the shovel and the dirt are moving. But when you stop the shovel, the inertia of the dirt keeps it moving and it leaves the shovel.

If you play basketball, you probably know that you must exert a force on the ball when you throw it toward the basket. Inertia keeps the ball moving. If it does not have enough inertia, it will fall short of the basket, and your team will lose the points.

REVIEW QUESTIONS

1. What is inertia? **2.** How is inertia overcome in starting a race or in stopping an object like a baseball? **3.** How does a swimmer use the inertia of water to move forward? **4.** How does a person use inertia in paddling a canoe or rowing a boat? **5.** What part does inertia play in the motion of airplanes? **6.** In what two ways is inertia a help? **7.** In what two ways is inertia a hindrance?

D How do we use energy in our environment?

Energy exists in two different forms. A piece of coal has energy stored in it. It is sometimes called "stored-up sunshine." But when the coal is burned, its stored energy is changed to heat energy. This energy change enables us to heat our homes. The coal contains chemical energy. The water at the top of a dam can do work if it is allowed to fall. It, too, contains stored energy. Energy which is stored up, as in coal, or in the water at the top of the dam, is *potential* (po-*ten*-shal) *energy.*

Falling water, wind, electric current, heat, and light possess a different type of energy. They can exert force because they are in motion. This energy of motion is *kinetic* (kin-*et*-ick) *energy.*

Energy is absorbed or given off when matter is changed from one form to another. Heat energy is absorbed when ice melts. This heat energy is

given off when the water freezes again. Heat energy is also absorbed when water changes into steam in a boiler. The heat energy released when the steam changes back to water in the radiators can heat a house.

When water evaporates, it changes from a liquid to a gas, so heat energy is again absorbed. That is why you feel cool when you stand outdoors in a wet bathing suit. The water, in evaporating, absorbs heat from your body. Your body feels cooler because heat is being taken away from it.

Your house is heated and your refrigerator is cooled by changing matter from one state to another. If coal is burned to produce heat energy, the potential (chemical) energy stored in the coal is changed to kinetic (heat) energy. Coal, which is a solid form of matter, is changed partly into gases.

Energy can also be changed from one form to another. We have already mentioned how the chemical energy of fuel is changed. In a telephone, sound energy is changed to electrical energy and back to sound energy again. In a flashlight, the chemical energy in the dry cells is changed to electrical energy. The electrical energy is then changed to light energy.

Thus man uses two kinds of energy: (1) the materials like coal which have energy stored in them (potential energy); and (2) the natural forms of energy like the wind and falling water (kinetic energy). When the first source is used, one kind of matter is changed to another, causing the release of energy. When the second source is used, one kind of energy is converted

Fig. 1-12. These football players are changing potential energy to kinetic energy.

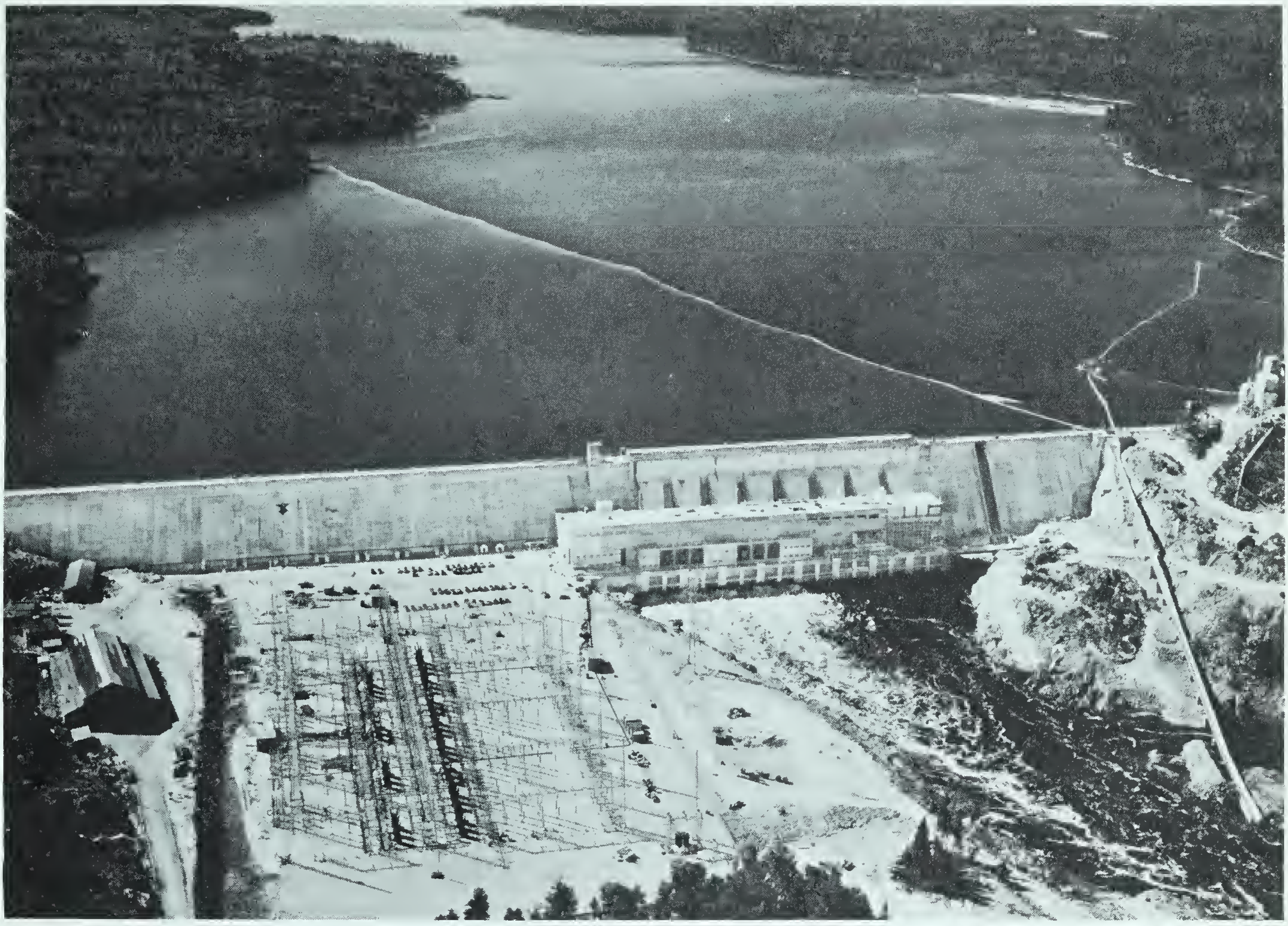


Fig. 1-13. Power plants such as the Des Joachims Generating Station on the Ottawa River enable man to convert the potential energy of water into kinetic energy. Name some other ways in which man has learned to use a natural form of energy.

into another kind. Can you think of examples to illustrate both methods of changing energy?

You use energy to overcome inertia and to do work. You need a certain amount of mechanical energy to set an object in motion. This energy is used to overcome the inertia of the object. You also need energy to overcome friction and to keep an object in motion. The energy does work by moving the object.

Mechanical energy is not the only type which you can use to overcome inertia and to do work. Electrical energy sets the gases in motion in neon signs. The chemical energy in coal does work when it heats water to a higher temperature and produces steam to drive an engine. In an automobile engine fuel is burned to produce heat. The heat causes gases to expand in the cylinders. Expansion of these gases is the driving force that pushes the pistons in the engine.

REVIEW QUESTIONS

1. What are the two forms of energy? **2.** What is the definition of each form? **3.** To which form does chemical energy belong? Heat energy? **4.** What is the earth's main source of energy? **5.** What energy changes occur in an electric light, electric stove, electric motor, gas engine, steam engine? **6.** Give five examples of how electric energy is used to do work.

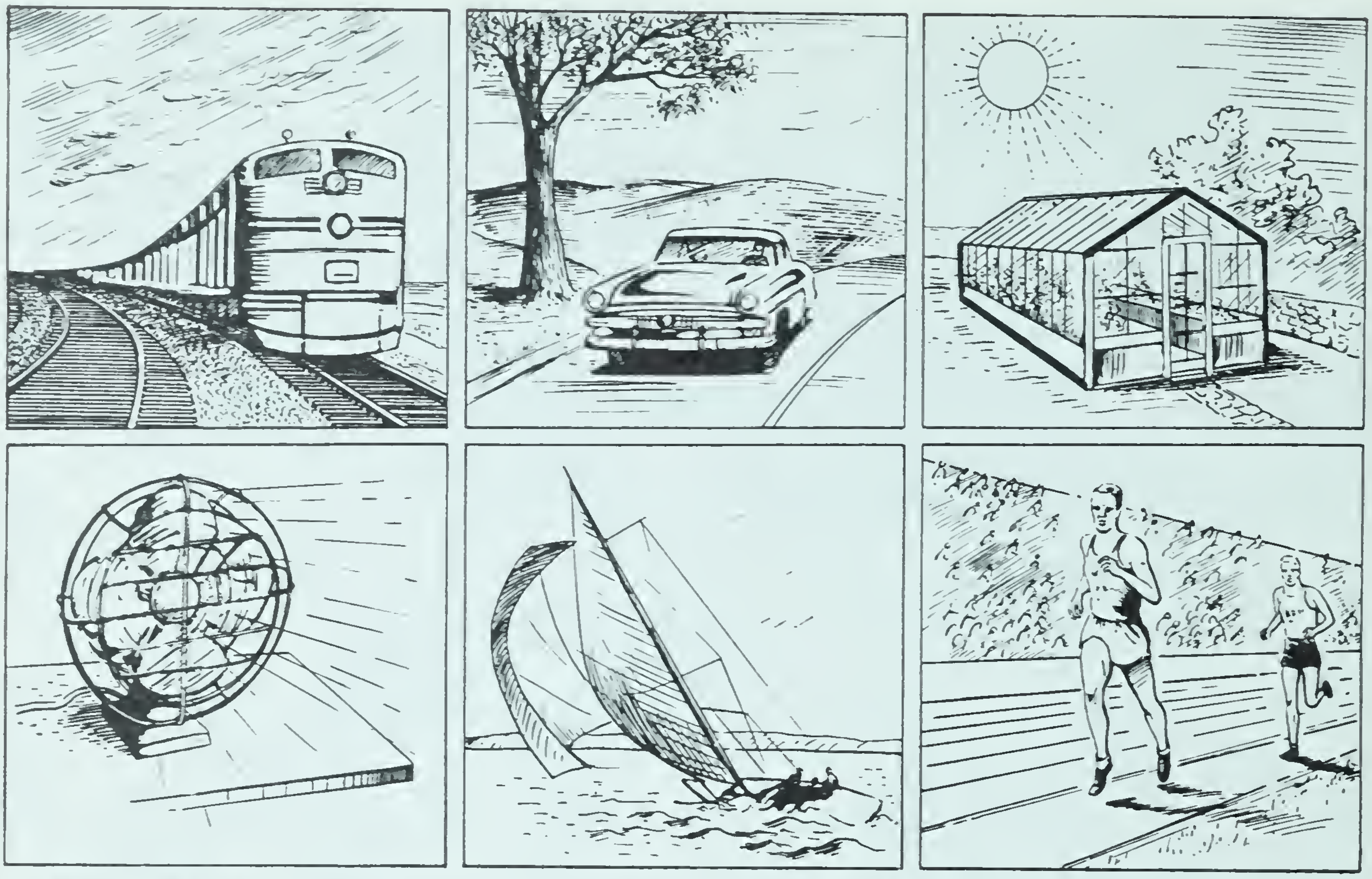


Fig. 1-14. What is the source of the energy used in each of the above illustrations?

E What has man learned about the relation of matter to energy?

All matter is composed of small particles called atoms. The *atom* is the smallest part of a chemical element that can exist and still have the properties of that element. An *element* is a substance which cannot be broken down into other substances by ordinary means. Copper is one example.

The central part of an atom is called the *nucleus* (*new*-klee-us). It contains two principal types of particles: (1) *protons* (*pro*-tonz); and (2) *neutrons* (*new*-tronz). Surrounding the nucleus, there are one or more *electrons* (eel-*leck*-tronz). (The atom of ordinary hydrogen has *only one proton and one electron.* It has no neutrons and is the *only exception* to the above statement.)

The atom contains a tremendous amount of energy. Scientists have

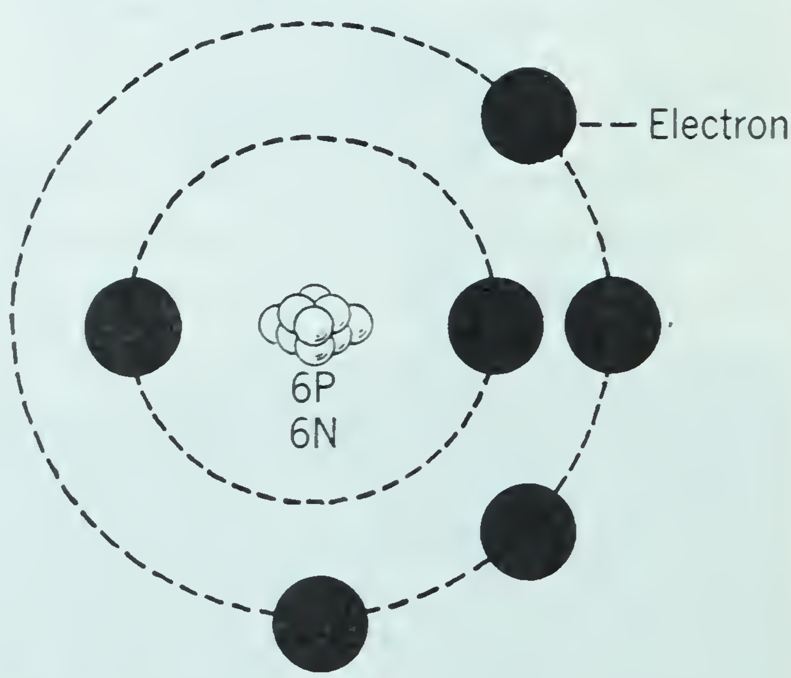


Fig. 1-15. This diagram shows the structure of a carbon atom. How is it different from the ordinary hydrogen atom?

proved this fact even though the atom is so small they cannot see it with the most powerful microscope. This energy is probably used in the atom to hold or bind the various parts of the nucleus together. When an atom-smashing machine splits an atom, part of this energy is released. This is the source of the *nuclear energy* which makes the atomic bomb so powerful. Nuclear energy is also being used to drive submarines in the United States Navy and preparations are being made to generate electricity by this means in Canada.

Scientists have for years changed raw materials into more usable forms of matter. They found that the total weight of the products formed was equal to the total weight of the materials used. Therefore they assumed that it would be impossible to ever destroy matter.

In the same way, scientists changed one form of energy into another form. And always the amount of the energy before and after was the same.

Scientists express these two facts that matter and energy can neither be created nor destroyed as natural *laws* or *principles*.

The two old laws of science that matter and energy can neither be created nor destroyed are now combined into a single law. Today, scientists have learned that some matter is lost when the atom gives up its energy. They had trouble proving this, but finally succeeded. The atom is so small, yet it releases so much energy for its size. It is very difficult to measure exactly what quantity of matter is actually lost in such nuclear changes.

For example, the amount of matter lost when you release energy by burning a substance is extremely small. In fact, you cannot weigh the amount of matter lost even on the most sensitive balance. The old laws of conservation of matter and energy have been combined as follows: *matter and energy cannot be created or destroyed by ordinary means, but they can be changed.* Thus, the total amount of matter and energy in the universe remains constant.

Early scientists thought of matter as being the most important part of the universe. Now we know that matter is another form of energy! A good example of matter being changed into energy is that of atomic, or nuclear energy. The term "nuclear" is much to be preferred to "atomic" because the energy really comes from the nucleus of the atom. When atoms are split or smashed, new atoms are formed and some energy is given off. If it were possible to weigh the new atoms formed, one would find that the new atoms weigh less than the original atom. The difference would be the amount of matter changed into energy.

REVIEW QUESTIONS

1. What are the principal parts of the atom? **2.** Describe the structure of the central part of an atom. **3.** What is lost when energy is released during the splitting of the atom? **4.** Which atom does not have any neutrons? **5.** Why should we use the term "nuclear" rather than "atomic" when discussing the change of matter into energy? **6.** What is the source of the power in atomic bombs?

F How has the scientific method helped man solve problems?

Problems result from the things we do or see. A scientist has a questioning mind. If he sees something happen, he wants to know why it happened. He wants to see the same thing happen several times to be certain it will always happen. What we see, and the questions we ask, depend on how much knowledge we have.

A good fund of knowledge enables you to make better observations and to ask better questions. That is the way a trained scientist tries to solve problems. A few great scientific discoveries have been made by accident. But most of them have been made only after careful work over a long period of time by men with many types of knowledge.

You can solve problems by the clear thinking and planning of the scientific method. In solving a problem by the scientific method, your thinking will usually go through the following steps.

1. *You do something or observe something happening.* You want to know why. You ask yourself a question. Now you have a problem to solve.

2. *You offer suggestions for solving the problem.* The suggestions come from your experience, your knowledge, and your imagination. Whether they are good suggestions or not will depend on how well you can think and plan.

3. *Next, you try out the suggestions or plans you have made.* You may read to get more information, talk with others, or observe similar occurrences. You may discard some of your suggestions. You may add others. In some problems, you may do steps two and three together.

4. *You make your final plan for solving the problem.* This is the blueprint from which you will work. It includes the experiments you will do and the observations you will make.

5. *You follow your blueprint and do your experiments.* If your blueprint is accurate, you will get results. If you have a real problem and do not know the answer, the blueprint you make may not be quite right.

6. *You summarize your results and any conclusions you have drawn.* If you do not get results, you will want to make a new blueprint and start over again. Few scientists ever get the right answer when they first try an experiment.

7. *If the results give you the answer to your problem, your blueprint was accurate.* But you are not quite finished! You must verify your results by many trials. If the same results occur each time you try, then you have the answer to your problem.

The scientific method allows only one factor to be changed during the same trial of an experiment. For this reason, we say it is a controlled experiment. If factor A is the only one allowed to change in several trials of an experiment, and the same result occurs in each trial, then you are sure that factor A produced the new result.

Suppose two factors, A and B, are allowed to vary in the same trial. The result may be produced by A alone, B alone, or by the combination of A and B. In such a plan, you have only one chance in three of knowing what produced the result. You can only guess which one produced the result.

But in a controlled experiment, only one factor is allowed to change in the same trial. The factor that is allowed to change is called the ***variable factor.*** Those which remain the same and which are not allowed to change are called the ***control factors.***

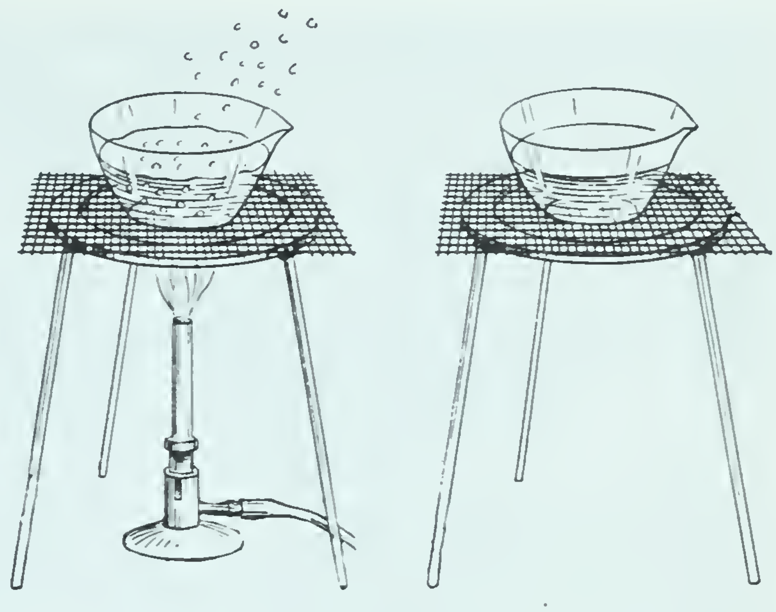


Fig. 1-16. How does this diagram illustrate a controlled experiment?

PUPIL ACTIVITY

In a general science class, a pupil asked the teacher what factors affected the rate of evaporation of water. Other pupils suggested that heat, size of the container, or moving air might have had some effect. Try these factors. (See Fig. 1-16.)

(A) Put equal volumes of water in evaporating dishes (or saucers) of equal size. Heat one dish for a stated time (5 minutes or more). Do not heat the other dish. Now measure the volume of water in each dish at the end of the experiment. Result? Conclusion?

(B) Put equal volumes of water in two containers of the same material but not of the same size. A test tube and a beaker are good for this experiment. Allow each to stand for twenty-four hours. Result? Conclusion?

(C) Put equal volumes of water in each of two containers of the same material and the same size. Let an electric fan blow air over one container. Put the other container in the same room but in a place where the air is not moving very much. Measure the volume of water in each container after the fan has been kept going for at least 30 minutes. Result? Conclusion?

What factors were controlled in parts A, B, and C? What factor was allowed to vary in each part? How did each factor affect the rate of evaporation?

The scientific method gives us a knowledge of science which helps to develop desirable attitudes. Many people are superstitious. This means that they have false beliefs about the causes of certain happenings. Suppose, for example, a person thinks that a rabbit's foot or a horseshoe can affect people's fortunes in games or business. A coincidence occurs, perhaps, and thus two quite unrelated happenings are thought to be cause and effect. People tell this to others, and a general belief arises which is entirely mistaken.

What are some common beliefs in your community? Are these based on good evidence?

In order to have a scientific attitude, you should be willing to change your opinions when you discover new evidence. In forming opinions or solving

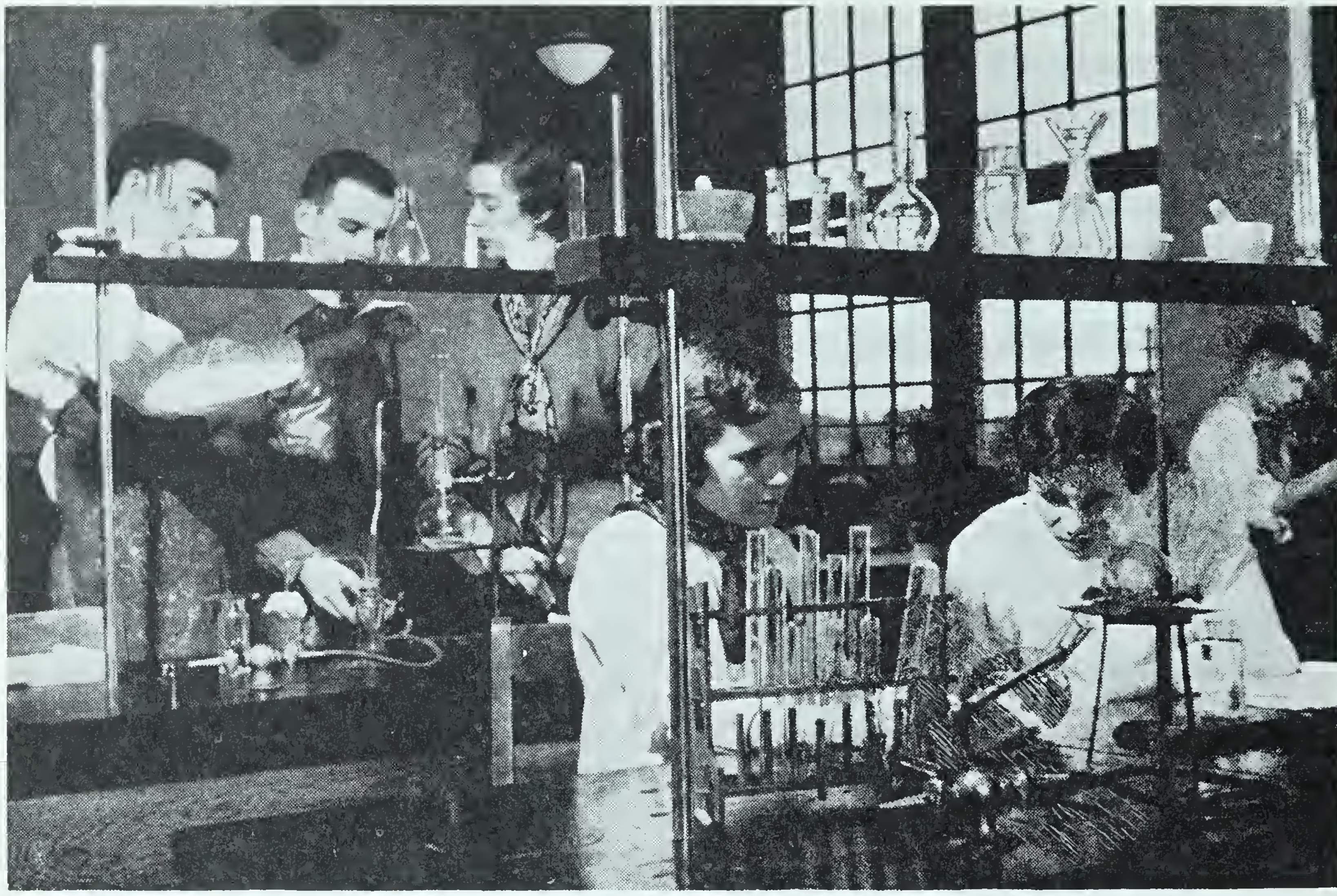


Fig. 1-17. The students shown here are developing desirable attitudes by using the scientific method to solve problems in the laboratory.

problems you should search for the whole truth, without prejudice. You should realize that there must be a cause for every happening.

In solving problems you must distinguish between fact and assumption. To find an explanation for things you do not understand, you should propose possible solutions for problems. But you must not consider these assumptions as facts until proven.

Ask yourself these questions every once in a while: Am I willing to change my opinions on the basis of new evidence? Do I search for the whole truth without prejudice? For every happening, do I try to find the true cause? Do I base my judgments on facts or do I let my feelings interfere with my judgments? Do I attempt to distinguish between fact and guesswork? Do I get rid of all fears and superstitions when I acquire facts which prove there is no foundation for these superstitions and fears?

REVIEW QUESTIONS

1. How do people become interested in scientific problems? **2.** What are the steps in solving a problem by the scientific method? **3.** What are the possible factors, or combinations of factors, which can cause a result when the three variables A, B, and C are allowed to vary at the same time? **4.** How must a scientist plan an experiment if he is to be certain of knowing what caused the result? **5.** What are controls and variables in an experiment? **6.** How can increase in knowledge help to improve your scientific attitudes?

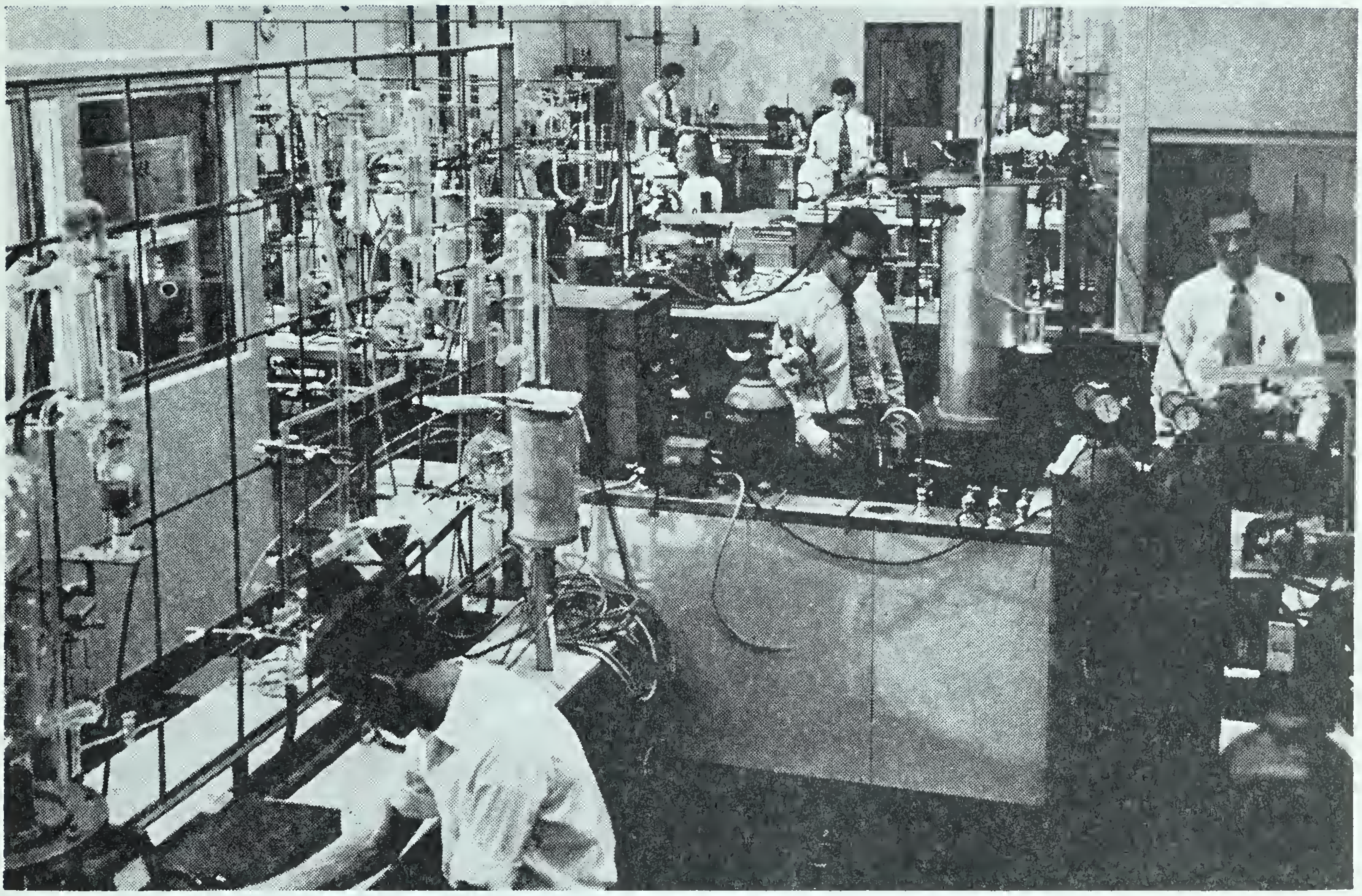


Fig. 1-18. Research scientists in industries, as shown in this metallurgy laboratory, solve problems by using the scientific method.

QUESTIONS FOR REVIEW AND DISCUSSION

1. How did ancient tribes and peoples solve their problems?
2. In what forms does matter exist?
3. Name three common properties of all matter.
4. How is matter changed from one form to another?
5. How can different forms of matter be identified and distinguished from each other?
6. How do we measure the volume that matter occupies?
7. How do we measure the weight of matter?
8. Give five common examples of inertia.
9. Explain how the force of gravity causes winds. Is the heavier or lighter air pulled nearer the earth?
10. Why does it require a greater force to start a wheelbarrow moving than it does to keep it in motion?

11. How do you define energy? What are the different forms of energy?
12. What energy changes occur when water from a dam supplies a power station that furnishes current for your electric light?
13. What method does the scientist use to solve his problems?
14. What are six desirable attitudes of the scientific mind?

SPECIAL REPORTS AND PROBLEMS

1. The methods the Greek scientist, Aristotle, used in his work.
2. The discoveries of Galileo.
3. The inventions and discoveries of Francis Bacon.
4. The superstitions of my community.

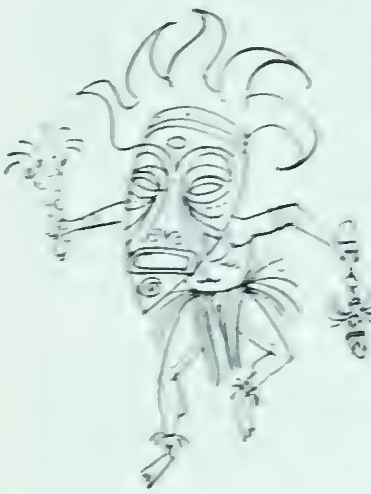
THE USE OF REFERENCES

A list of a few books well worth your reading appears in the Bibliography at the end of this book. Books give additional information and will be helpful in getting material for special problems and reports. The various encyclopedias will give you even more information. Your school librarian will also help you on many topics.

TESTING THE PURPOSES OF THIS UNIT

1. Many new words are used in science. You should be able to define each word accurately. Define the following words or terms: environment, matter, space, gravity, force, weight, inertia, energy, scientific method, and scientific attitude.
2. Why was it necessary to reconsider the old statements of the laws of the conservation of matter and energy?
3. What governmental agency in your community is responsible for checking the accuracy of the weights used by places of business? What can the purchaser do to check the accuracy of the weights of the fuel he buys?
4. How is inertia overcome or made use of in swimming, stopping an automobile, starting an automobile?
5. What apparatus would you use to measure your height? How would you test the accuracy of the apparatus? The accuracy of your measurements?
6. What different forms of energy are used in your home and school? What is the source of each form of energy?
7. Assume that you were given the problem of building a garage. What steps would you follow in building the garage if you used the scientific method?
8. What scientific attitudes are applied when a person becomes tolerant of other people's ideas or interests?
9. How do fears and superstitions originate? How may they be overcome?
10. Assume that some unknown disease has caused many deaths in a community. How could the scientific method be applied to discover the cause?

The old

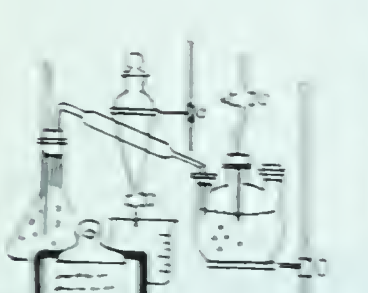


IN ANCIENT TIMES PEOPLE WERE GOVERNED LARGELY BY fear and superstition. Today science has made us much less superstitious. We depend more and more on facts for solving our problems.

The nature of matter and energy was a mystery for a long time. Now we know how to change matter from one form to another. And by chemical means, we can make new kinds of matter. We have learned to control energy and to change it from one form to another. We have learned how to make it do work for us.

However, the exact nature of matter and energy is not entirely understood even today. But scientists are constantly experimenting to develop new theories to explain the nature of matter and energy. These theories are generally accepted because evidence from actual experiments supports them.

The new



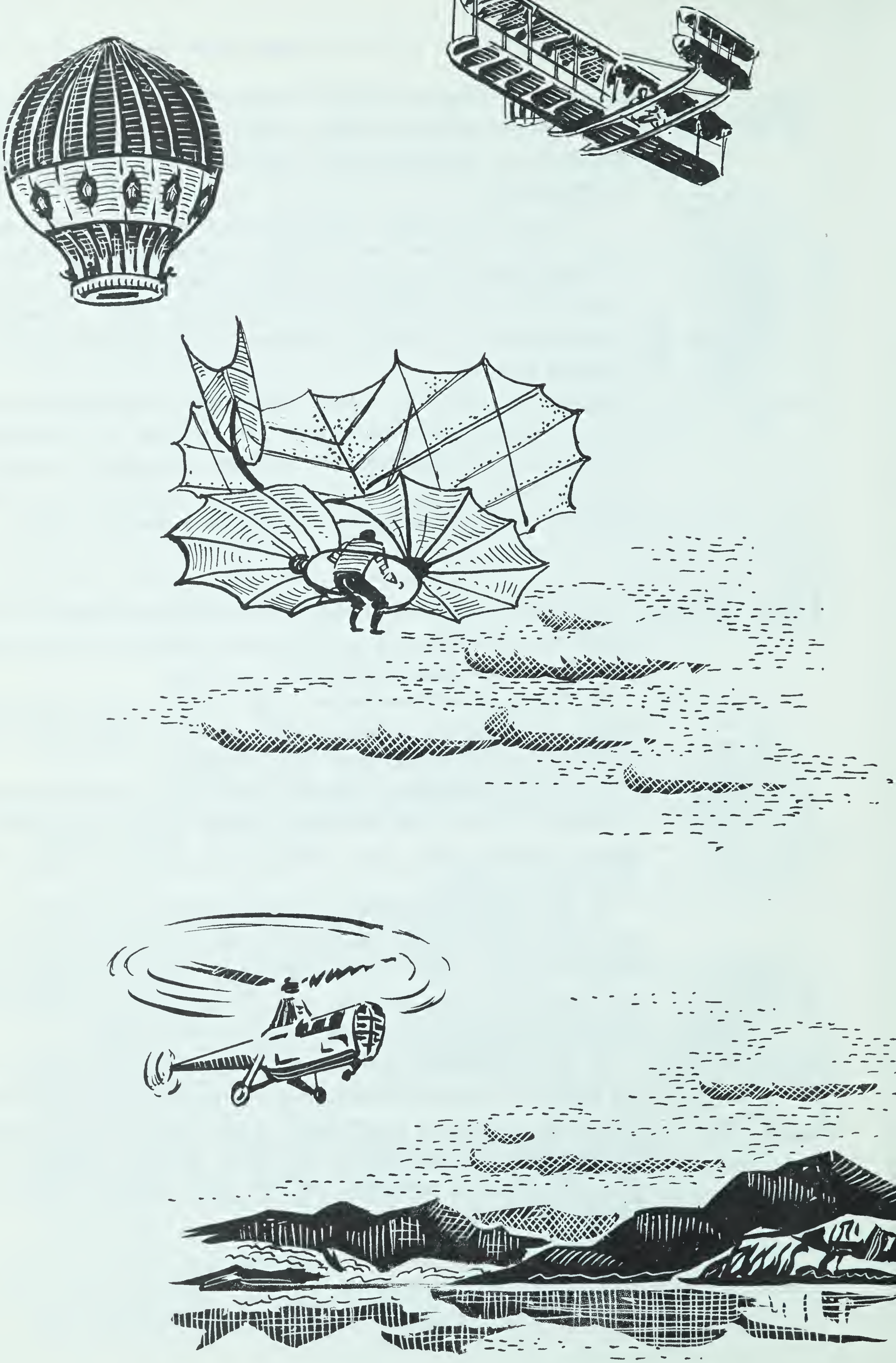
THE SCIENTIFIC METHOD WAS NOT DEVELOPED SUDDENLY. IT passed through at least four stages, and methods now used can usually be put in one of the four.

1. *The Superstitious-Belief Stage.* People often base their beliefs on emotions without good evidence. Superstitions are no more to be accepted than chance guesses.

2. *The Authoritative-Opinion Stage.* Many people accept statements as true just because someone who is supposed to know said they were true. Many of our social problems are now in this stage.

3. *The Observation Stage.* Many people say they will believe only what they see. But they do not always see what they think they see. One's own beliefs may make one blind and allow him to see just what he wishes to see. Only by observing without prejudice will you see what is actually there.

4. *The Controlled Experiment Stage.* When only one factor changes in an experiment, that factor must bring about the result. By a series of experiments, each factor may be varied while others are controlled so the effect of each is learned. If the experiment is repeated, and the same result occurs, the result must be accepted.



UNIT 2

How has man learned to use air pressure?

DISCOVERY AND PROGRESS

EARLY man knew very little about air. He thought that the earth, sea, and sky were all mixed together. As recently as the 18th Century man thought that earth, air, fire, and water were chemical elements and therefore could not be changed into anything else.

In the 17th Century the Italian scientist, Galileo (gah-lih-*lee*-oh), planned experiments to prove that air had weight. He died before he could complete his work so his pupil, Torricelli (toh-rih-*chell*-ee), continued this. Torricelli weighed a flask which was partly filled with air. Then he weighed the same flask containing much more air. The vessel which had the larger amount of air weighed more, showing that air had weight. Because of this fact, Torricelli concluded that air exerted a pressure. He studied the effect of air pressure on the water in a

well and found that air pressure will not push water up in a vacuum tube more than 34 feet. He reasoned that since mercury was much heavier than water, air pressure would not lift it so high. Thus, he could use a shorter tube with mercury in it instead of water. As a result of this experiment, the mercury barometer was invented and Torricelli learned how to measure air pressure. This type of barometer is still in use today and is one of our most valued instruments in forecasting the weather.

After Torricelli's death, his work was carried on by the French scientist, Pascal (pass-*kal*), who lived in the 17th Century. Pascal thought that since air pressure held the mercury up in a vacuum tube, a lower than usual air pressure would cause the mercury level to fall. He tried his experiments on the top of a high mountain and found that the mercury level fell three inches as he climbed the mountain.

Meanwhile, other scientists found that when they took a small balloon, partly filled with air, to a mountain top, it would expand until it appeared to be quite full. They noted that it shrank as they brought it down from the top of the mountain and therefore concluded that the outside air pressure changed with a change in altitude.

Records indicate that man has always wanted to fly even in the earliest times. The reasons he failed are due to the fact that he knew practically nothing about air pressure. Mythology and folklore abound with stories about man's efforts to fly. There was Icarus, a mythical Greek who hoped he could fly by making a pair of wings from bird feathers. Unfortunately, his attempt failed completely. Then early in the sixteenth century the Italian artist, Leonardo da Vinci (lee-on-*ar*-doh dah *vin*-chee) tried to make a flying machine. He drew careful plans before he began to build it and believed that if he made the wings flap like those of a bird his machine would get off the ground. But he, too, failed. It was not until 1783 that man was able to build a machine which would take off and actually fly. This was a balloon which was invented in that year by the Montgolfier (mon-*goh*-fee-yeh) brothers in France. It has been drawn in the panel facing page 27 and appears in the upper left-hand corner.

In 1896, Samuel P. Langley, an American, built his famous steam-powered "Aerodrome." It was the first airplane to fly under its own power; but did not carry a pilot. Later, the Wright brothers, following the experiments and discoveries of earlier inventors, made the first practical airplane. They first flew it in 1903 at Kitty Hawk, North Carolina. Their plane is shown in the upper right-hand corner of the panel facing page 27.

Progress in aviation has been rapid since the Wright brothers first flew. Today we have helicopters, fast transport planes, and even faster jet planes. Man has achieved one of his earliest wishes—to fly.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. Is air a real substance? **2.** Why is it better to have two holes in a can if you expect to pour out its contents easily? **3.** Why does a tennis ball not bounce well after it has been punctured? **4.** How do we measure air pressure? **5.** How can you measure the air pressure in your bicycle tire? **6.** What makes a toy popgun pop? **7.** What makes the gurgling sound when you empty water from a bottle or jug? **8.** What keeps a kite in the air? **9.** How are airplanes able to stay in the air and move if they are heavier than air? **10.** What kind of gas is used to fill balloons? **11.** What are pneumatic appliances?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

air pressure	the force which air exerts on each unit area it touches.
airfoil	any curved surface of an airplane that increases lift or thrust.
altimeter . .	a special type of barometer used in airplanes to indicate altitude.
barometer .	a device to measure air pressure.
buoyancy .	(*boy*-an-see), the upward force exerted on a submerged or floating object by a liquid or gas.
caisson . . .	a large device that uses compressed air to allow men to work under water.
compressed	squeezed into a smaller space.
drag	the resistance offered by air to an airplane which is moving through it.
exhaust pump	a pump used to remove air or other gases from a container.
lift	the upward force exerted on the wings of an airplane by moving air.
molecule . .	(*moll*-uh-kūle), the smallest quantity of any substance which exists and has the properties of that substance.
partial vacuum . . .	a space in which the pressure is lower than normal.
pneumatic .	(new-*mat*-ick), pertaining to air or air pressure.
thrust	the force that moves an airplane forward.
vacuum . . .	space which is empty of all matter.

A What is air pressure?

Air pressure is the force which air exerts on each unit of area it touches. In Unit 1, we learned that all matter has weight and occupies space. Anything that has weight can exert pressure. We define *pressure* as the force which matter exerts on each unit of area it touches. Since air is a form of matter, it has weight and exerts pressure.

DEMONSTRATION

Fill a tumbler with water and put a piece of pasteboard coated with liquid paraffin over the top as shown in Fig. 2-1. Turn it over carefully. Explain why the pasteboard acts as it does. Then hold the tumbler sidewise. Where is normal air pressure? What holds the pasteboard on the tumbler? Note that the air presses sidewise as well as upward.

Usually the upward force of the air is enough to support balloons and dirigibles. A blownup football or basketball is firm all over because air presses in all directions.

Air exerts a pressure all the time, but we notice it only when the pressure is unbalanced. This is because its pressure is usually balanced by an equal amount of pressure in the opposite direction. For example, the pressure on one side of a door is usually balanced by a like pressure on the opposite side. Now what happens when the wind blows a door open? The door is pushed in from the side on which the wind is blowing. *Something usually moves when there are unbalanced pressures or forces.*

DEMONSTRATION

Get a large can with a neck into which you can fit a stopper (a maple syrup can or one used for holding denatured alcohol). Pour a little water into the can and heat it over a gas flame until steam comes out. Remove the can from the flame. Now stopper the can tightly and quickly put it under the cold water faucet or into a pail of cold water. Result? Conclusion? What was the effect of the steam? (See Fig. 2-2.) (NOTE: This demonstration may be performed also by exhausting the air in the can by means of a good exhaust pump.)

Does air press in on all sides of the can? At first the air pressure on the inside was equal to the pressure on the outside of the can. After the sealed

Fig. 2-1. Air exerts pressure all the time and in all directions.

can was cooled, the air pressure inside was less than the pressure outside so the sides of the can were crushed.

When the steam was made, part of the air in the can was pushed out. The steam and the air could not both be in the can at the same time. When the can was sealed and put into cold water, the steam was changed into water. The water did not occupy as much space and a reduced pressure was created. Thus the pressure inside the can was less than the outer air pressure. The can was crushed by the air pressure from all directions on the outside.

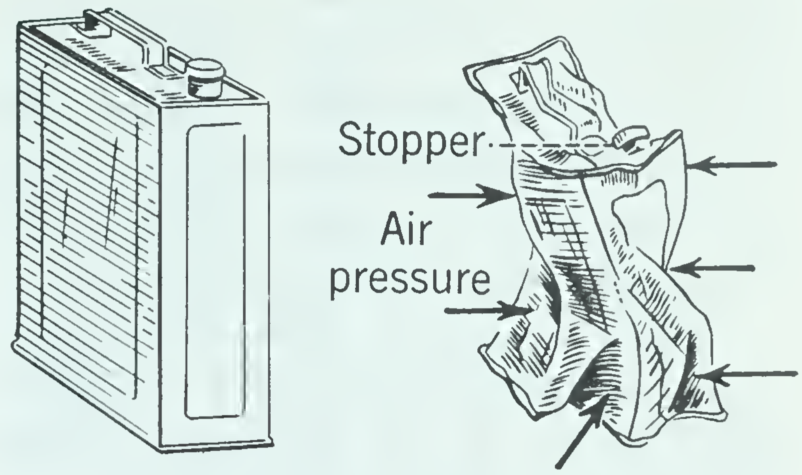


Fig. 2-2. The can is crushed by a difference in air pressure.

DEMONSTRATION

Fill a tumbler with water, cover it with a card, and invert the whole in a basin of water as shown in Fig. 2-3. Remove the cover. Pass a piece of rubber tubing under the water and up to the top of the tumbler. What holds the water in the tumbler? What keeps the air pressure from being the same on the top of the column of water as on the bottom? Blow into the tube. Result? Conclusion? Suck out some of the air. Result? Conclusion?

When you fill the tumbler with water, all the air is driven out of it. The pressure on the water in the basin keeps the water in the tumbler. When you blow air into the tumbler, the pressure of the air inside soon is equal to that on the outside. The water falls to its level in the basin. If you suck the air out, the water rises again because the pressure of the air inside the tumbler is less than that outside.

Air pressure is due to the movement of molecules. The air contains several different gases. Each of these gases is composed of very small invisible particles called *molecules* (*moll-*

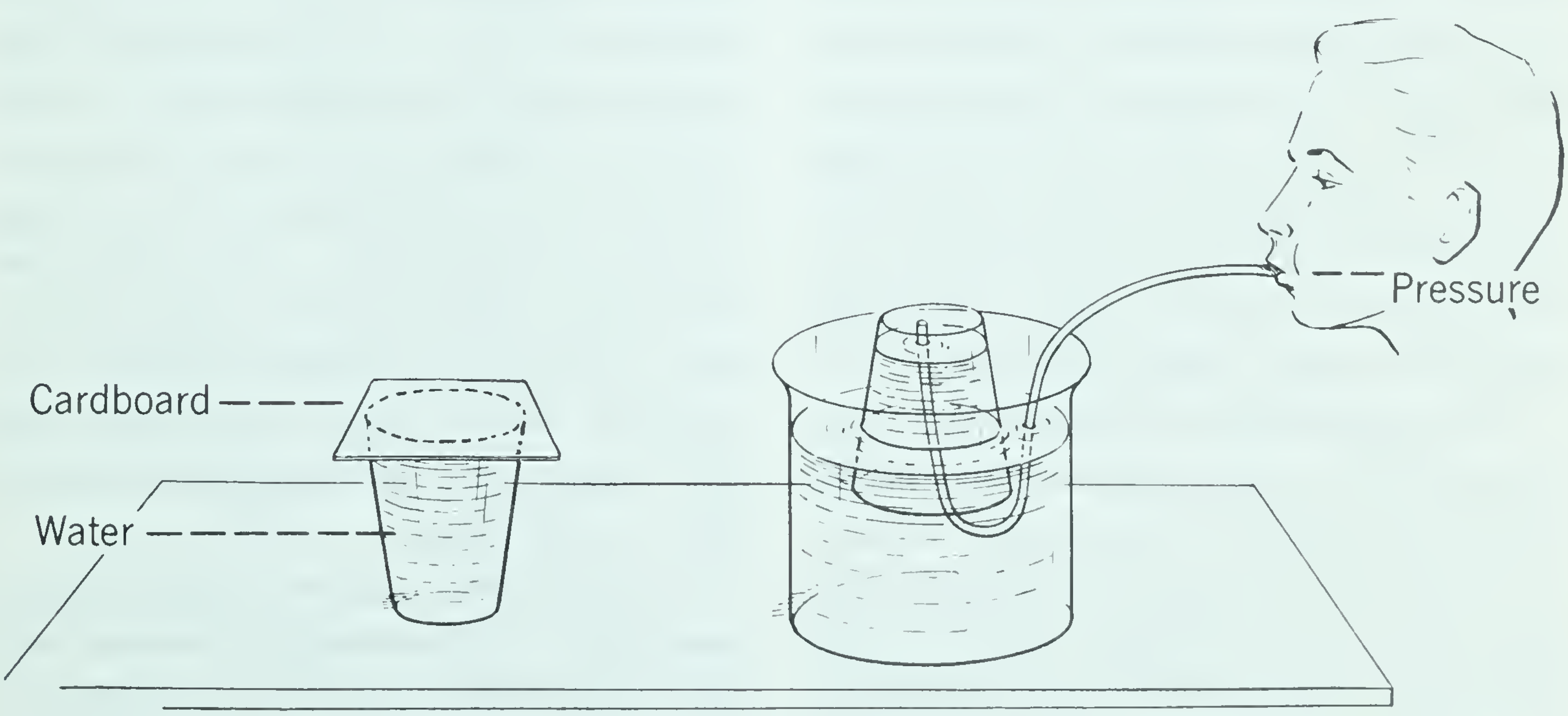


Fig. 2-3. What conclusions do you draw about air pressure after these two experiments?

uh-kules). A *molecule* is the smallest quantity of a substance which exists and has the properties of that substance. Each molecule consists of one or more atoms. The particles of air are too small to see with a microscope.

There are many millions of molecules of different gases in a small volume of air. If air has weight, each molecule must also have weight.

Molecules of gases in air are always moving rapidly. When millions of these molecules moving at high speed hit something, they produce a *pressure*. We can compare this pressure of the molecules of the gases in air with the pressure produced by tennis balls hitting a wall. Suppose that automatic pitching machines were throwing the tennis balls against the wall. The balls are being thrown one right after another. You can see that the pressure on the wall would depend on two things. First, it would depend on the number of tennis balls hitting the wall. Four machines would produce a larger pressure than one. Second, it would depend on how fast the tennis balls are going when they hit the wall. Fast tennis balls will produce a greater pressure than slow ones. It is the same thing with molecules of the gases in air. The total force depends on the number of molecules and the speed with which they strike a surface.

This explains how a difference in air pressure can occur between the inside and the outside of the same surface. If air is removed from a container, the pressure inside decreases because there are fewer molecules to push against the sides. The pressure on the inside is then less than the pressure on the outside. In the same way, more air can be forced into a hollow container, and the pressure inside is increased because there are more molecules pushing against the sides. The pressure outside is then less than that inside.

Automobile tires are an example of the use of unequal air pressures on the inside and outside of the same surface. A gauge pressure of 30 pounds per square inch in a tire means that the force inside is 30 pounds greater per square inch than on the same area outside. *The total force of the air is equal to the pressure (which is force per one square inch) times the number of square inches.* A pressure of 30 pounds per square inch in the tires will support an automobile weighing two or three tons. This is possible because the pressure per square inch times the number of square inches of the tires resting on the ground is equal to the total weight of the automobile.

Air pressure can be changed by removing air from, or by adding air to, a given space. It is easy to change the amount of air in a given space. This means that a given space may contain twice as much air at one time as at another time. When you pump a large volume of air into a rubber tire, the tire does not become any larger noticeably. The air pressure inside it increases. If the tire is punctured, the air rushes out. So the pressure inside the tire decreases.

Air pressure can be changed by increasing or decreasing the volume of a given amount of air. The movement of molecules explains why we can change

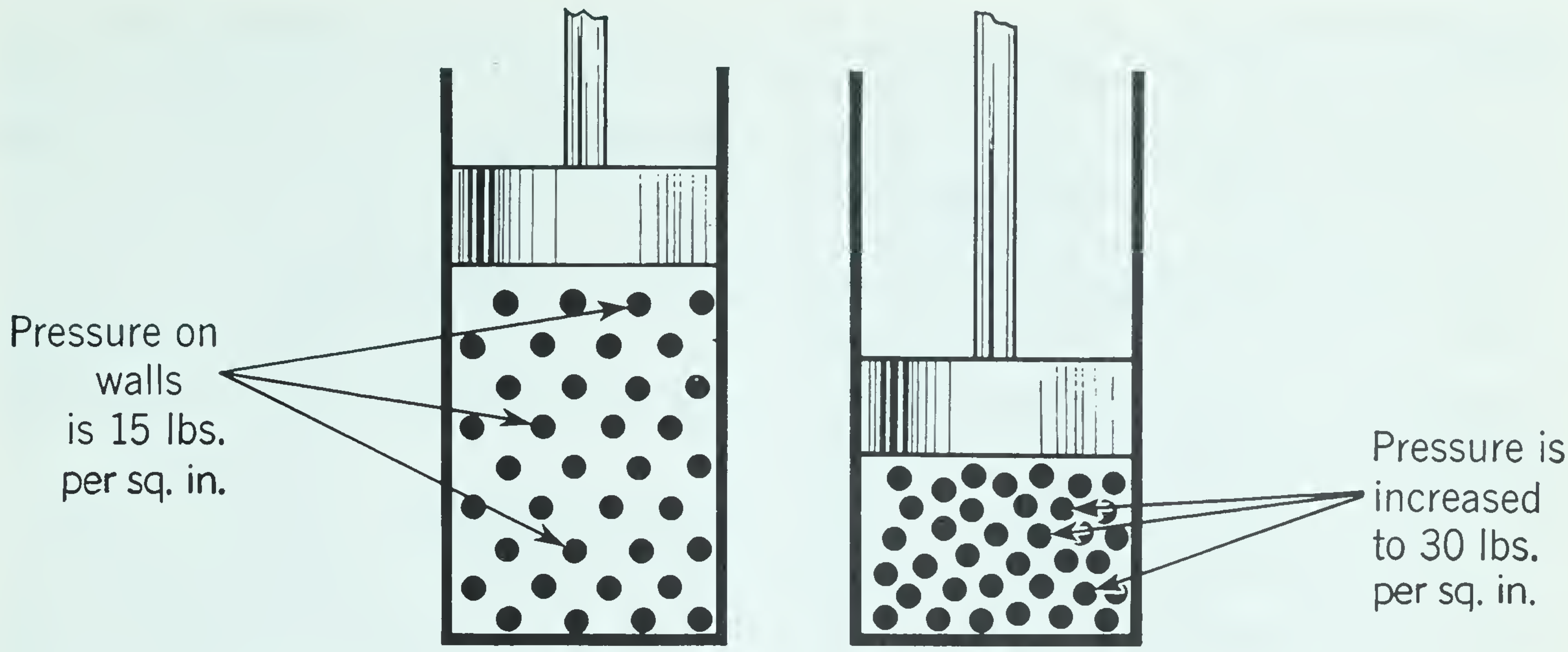


Fig. 2-4. The molecules of the gases in air are pushed closer together when you move an airtight piston down a cylinder.

the volume of air so easily. When the volume of a given amount of air is reduced, we say the air is *compressed.* In other words, the molecules of gases in air are being pressed closer and closer together. When a given amount of air fills a larger volume, the distance between the molecules becomes greater.

If we move an airtight piston down a cylinder (Fig. 2-4), the air is pushed into a smaller space. Its volume decreases. The pressure increases because the same number of molecules are striking a smaller area. If the volume is decreased by one-half, the pressure is twice as much at constant temperature. This is because twice as many molecules are striking each square inch of area. When we move the piston up in the cylinder again, the molecules fill the whole volume of the cylinder.

Air is elastic. What happens when you press the two ends of a coiled spring toward each other? What happens when you stretch the spring by trying to pull the two ends apart? The elastic energy in the spring tends to bring the spring back to its original size and shape. Air has this same property of elasticity. When you squeeze air molecules together, the air is *compressed.* When you release the squeezing force, the air molecules move farther apart, and the air *expands.*

Do you know how the elasticity of air is used in the toy popgun? When you draw back the plunger and insert the cork, you have filled the barrel of the gun with air. When you let go the plunger by pulling the trigger, you are compressing this air. The compressed air in the barrel exerts a force on the cork. This force is great enough to push the cork out of the gun.

When an inflated basketball strikes the floor, the sides are pushed in and the air is compressed. The compressed air then pushes the sides back and this makes the ball bounce. Tennis balls act in the same way. Many devices have been developed which put to use the elastic energy of air. Some examples are: the airbrakes of a train, the bean shooter, and the air-rifle.

REVIEW QUESTIONS

1. What is air pressure? **2.** How do you know that air presses equally in all directions? **3.** What are unbalanced air pressures? **4.** How is air pressure increased in an automobile tire? **5.** Does a certain weight of air always have the same volume? **6.** How is air pressure explained by the movement of molecules? **7.** How many square inches of each tire will be touching the ground if a four-wheeled truck weighs two tons loaded, and the gauge pressure in the tires is 75 lb. per sq. in.? **8.** Why can the braking power of a heavy truck or bus be increased by increasing the number of wheels? **9.** How can the pressure of air be changed? **10.** Why do we say that air is elastic? **11.** Why do basketballs become round when they are filled with air?

B How is air pressure measured and how are the measurements used?

Torricelli discovered the principle of the barometer. Aristotle thought that air had weight, but he could not prove it. In the 17th Century, Galileo noted that he could not raise the water in a well more than 32 feet with a suction pump. He knew that air had weight, and perhaps he suspected that the pressure the air exerted was equal to the pressure of a 32-foot column of water. Actually, pumps in his day did not have a very good vacuum. Today we know air exerts a pressure that will support a column of water 34 feet high.

Galileo's pupil, Torricelli, then reasoned that if the atmosphere could support over 30 feet of water, it should be able to hold up a column of about 2½ feet of mercury, since mercury is 13.6 times heavier than water. The following shows how Torricelli made his mercury barometer (bah-*rom*-eh-ter).

DEMONSTRATION

Get a glass tube about 34 inches long and closed at one end. Fill the tube with mercury to remove the air. Close the open tube with your finger and invert the tube as in Fig. 2-5.

Put the open end into a bowl of mercury. Remove your finger. Result? How high does the mercury remain in the tube? Tip the tube toward one side. What is the vertical height? Where has a vacuum been created? What is a vacuum? Can there be any air pressure on the mercury at the top of the tube? What prevents it?

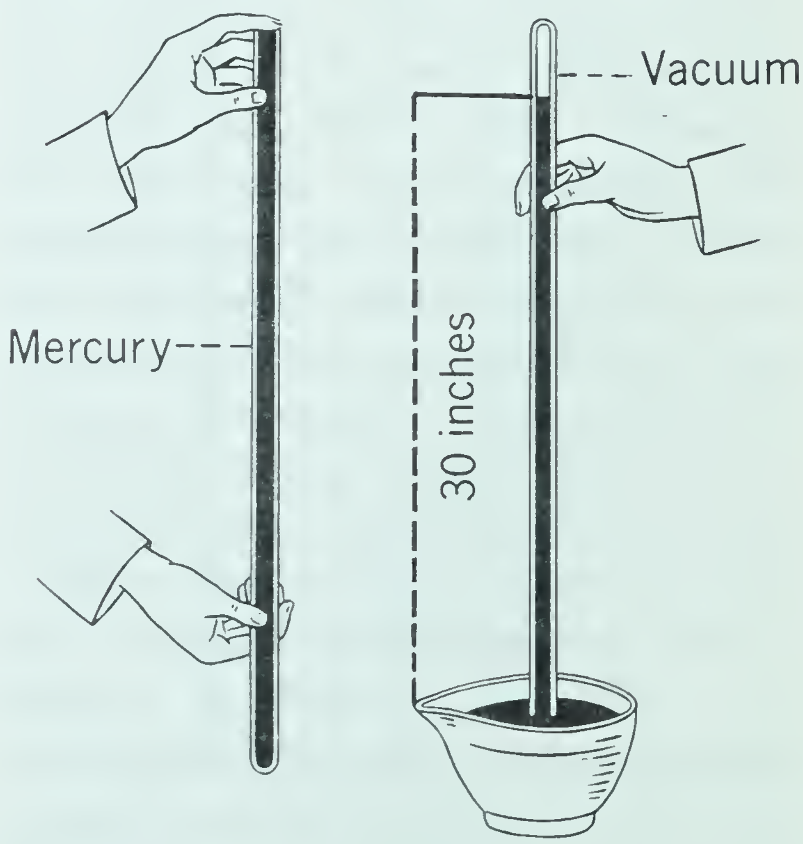


Fig. 2-5. Air pressure holds up a column of mercury approximately 30 inches high.

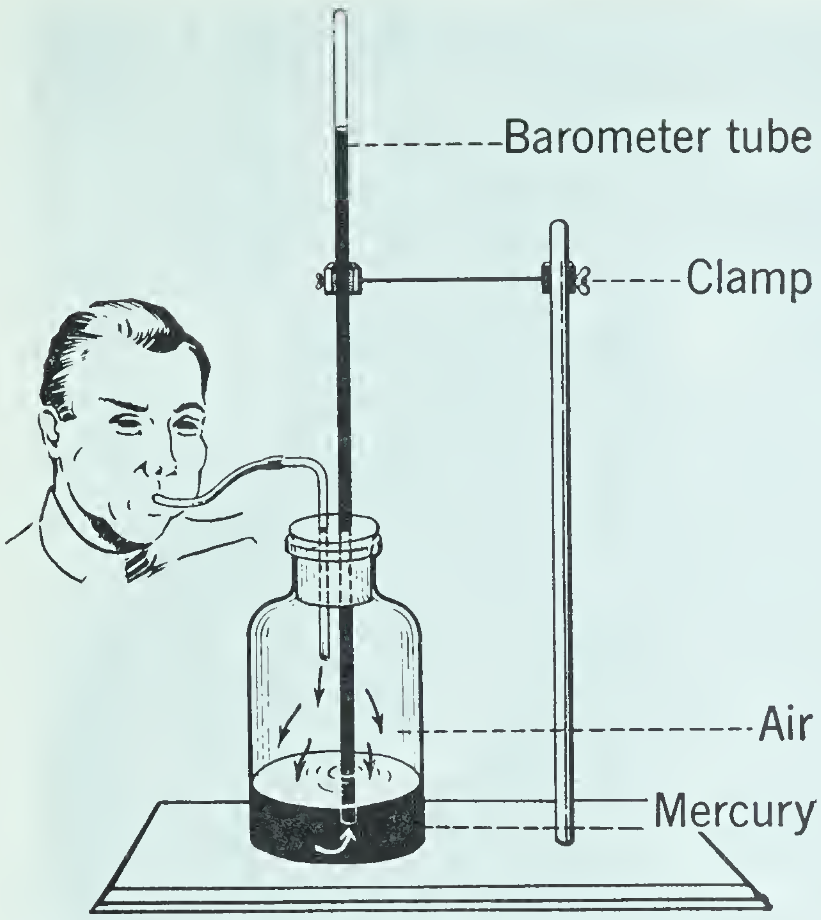


Fig. 2-6. As the pressure changes so does the height of the column of mercury in the barometer.

Remove the mercury from the barometer tube by raising it so that the lower end is above the mercury in the bowl. Now set up another barometer, using a bottle as in Fig. 2-6. Suck on the rubber tubing attached to the short tube through the stopper. Result? How is the mercury affected in the barometer tube? What determines the height at which the mercury stands in the barometer tube?

The barometer measures air pressure. The air pressure on the mercury in the bowl just balances the pressure of the mercury in the tube. An air column reaching from the earth's surface to the top of the atmosphere has the same weight or pressure as a column of mercury of the same cross-sectional area, about 30 inches high. A 30-inch column of mercury with a cross-sectional area of one square inch weighs about 14.7 pounds. This is the way scientists found out that air pressure is about 14.7 pounds to a square inch of surface at low altitudes. This is an *average pressure.* It changes according to the altitude, the amount of water vapor in air, and the speed of air currents.

Because of long usage, we speak of 15 pounds per square inch as a pressure of **one atmosphere.** And 150 pounds per square inch pressure is ten atmospheres. Tire gauges measure the pressure in pounds per square inch. When a tire gauge reads 30 pounds, it means that the pressure inside the tire is 30 pounds per square inch more than it is on the outside. The total pressure inside the tire is really 45 pounds per square inch. This (45 pounds) would be the reading of a gauge that reads zero in a vacuum. Why?

Aviators measure the air pressure to find the altitude at which they are flying. Air pressure decreases as the altitude increases. This means that there are fewer molecules in a cubic foot of air at high altitudes than there are at low altitudes. Because there are fewer molecules the pressure is less. If the barometer reading on the ground is 30 inches, then at 900 feet altitude it is approximately 29 inches. At 1,800 feet it is approximately 28 inches. The barometer falls about *one inch for each 900-foot increase in altitude.*

There is a special form of barometer which is used to measure altitude. We call it an *altimeter* (al-*tim*-uh-ter). Altimeters are graduated to read in feet of altitude and are one of the most important devices on the instrument panel of a modern airplane.

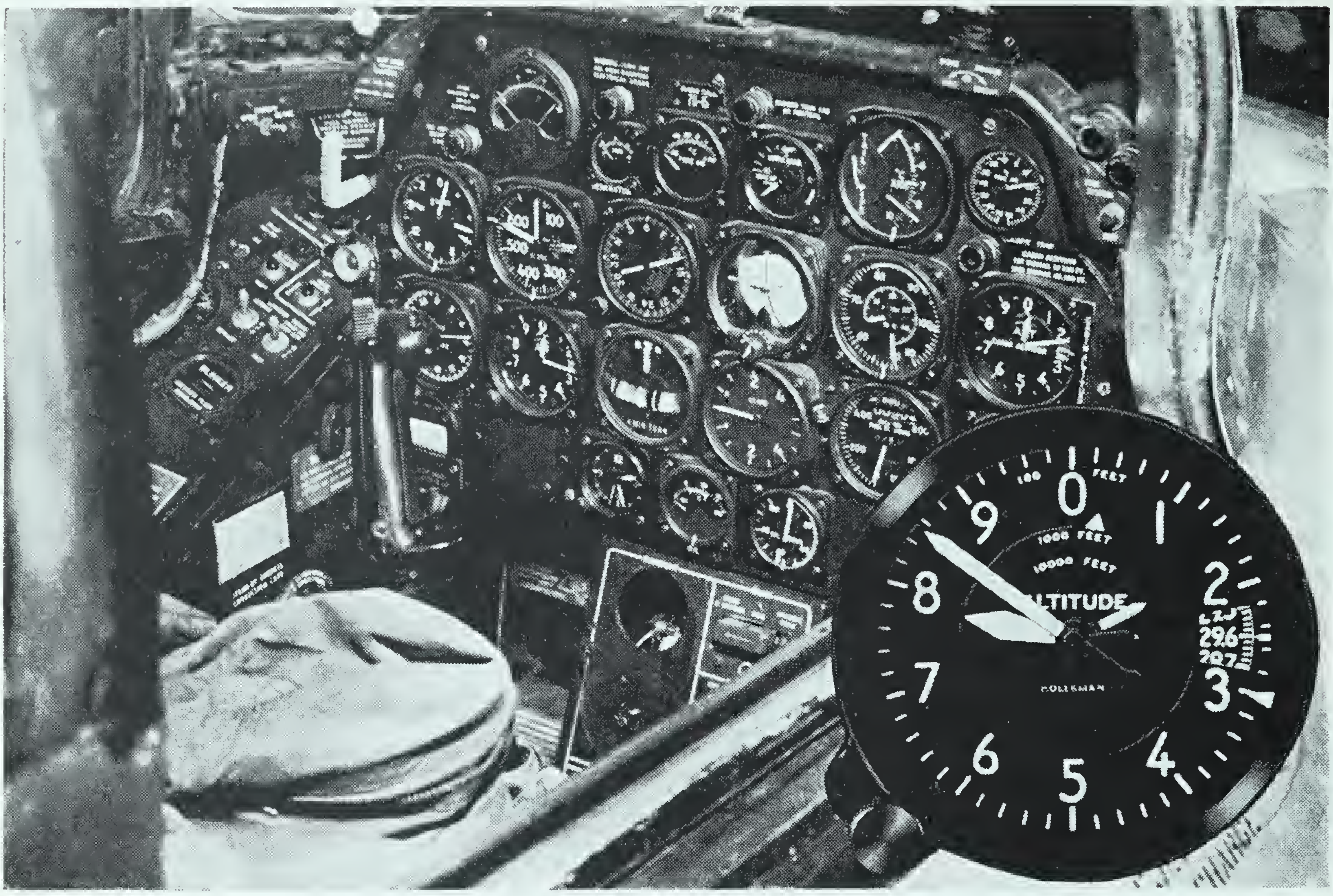


Fig. 2-7. The altimeter (insert at the right) is one of the most important instruments on the instrument panel of a modern airplane.

Weather forecasters measure air pressure to predict weather. There is a close relation between the pressure of the air and the amount of water vapor in it. Air pressure decreases as the percentage of water vapor in the air increases. The reason for this difference in weight is that water vapor is lighter than dry air. Twelve cubic feet of dry air weigh approximately one pound at normal air pressure. But one pound of water vapor occupies between seventeen and eighteen cubic feet at the same pressure.

If water vapor is mixed with air, both of them are free to expand. In the atmosphere the mixture becomes lighter than dry air. And if the pressure is less, the level of the mercury in the barometer will fall. A low barometer reading indicates that the air may contain a considerable amount of water vapor. In Unit 5 we shall learn more about the effects of air pressure.

REVIEW QUESTIONS

1. Who first measured the pressure of air? **2.** Why is mercury rather than water used in a barometer? **3.** How high will air pressure hold a column of mercury? Of water? **4.** What is the normal pressure of air in pounds per square inch? **5.** Why is the barometer tube filled with mercury before it is inverted in the bowl of mercury? **6.** What is a vacuum? **7.** What is five atmospheres pressure? **8.** Why is the reading of the barometer lower at higher altitudes? **9.** How does the addition of water vapor affect the pressure of air? **10.** Calculate the weight of dry air at normal pressure in your classroom.

C How is air compressed and used in pneumatic appliances?

Air pressure can be increased by using a compression pump. Compression pumps are used to increase the pressure of air above the normal pressure of 15 pounds per square inch. One type of compression pump appears in Fig. 2-8. The piston fits the cylinder tightly and has no valves. The valves at the bottom of the cylinder are arranged so that air enters on one side and leaves on the other. On the upstroke of the piston the air in the lower

Fig. 2-9. This service station attendant is filling a tire with air from an automatic compression pump which is regulated by an automatic pressure gauge.

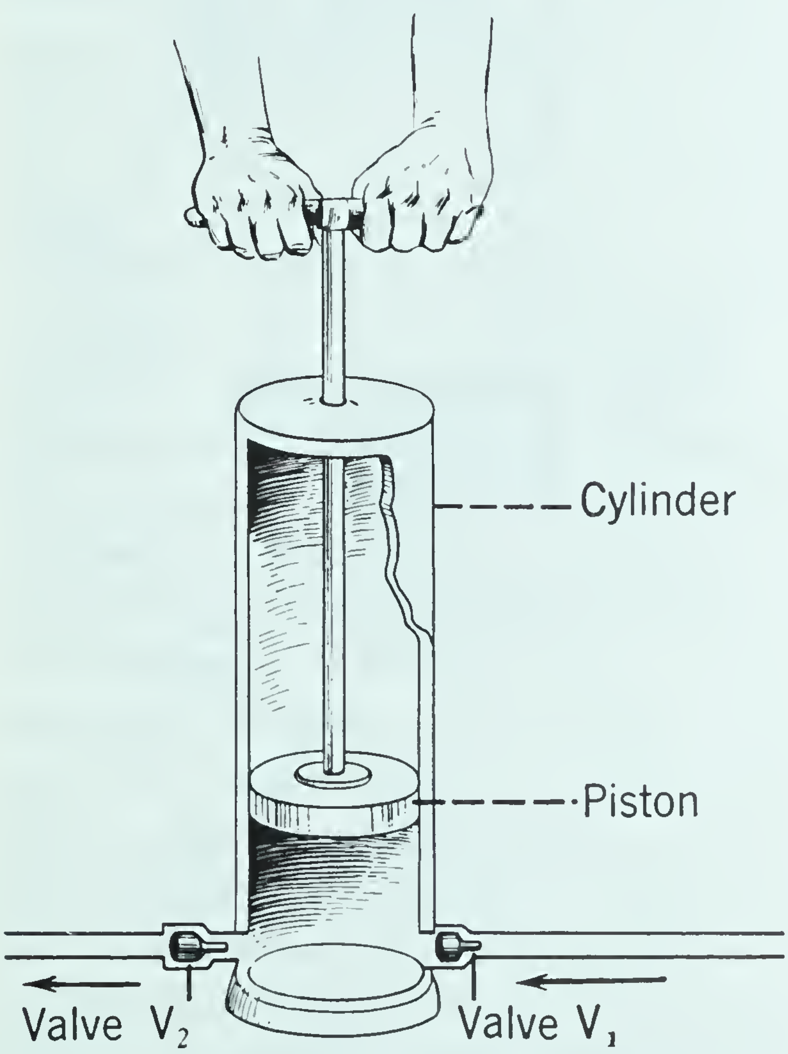


Fig. 2-8. You can increase air pressure by using a compression pump.

part of the cylinder expands and the pressure is reduced. The outside air pressure opens valve V_1 and closes valve V_2. Air flows into the cylinder through valve V_1 to equalize the pressures.

On the downstroke, the air is compressed. This compressed air opens valve V_2 and closes valve V_1. The result is that air is forced through valve V_2. This compressed air may be forced into a tire, a football, basketball, or any other object needing increased air pressure.

A bicycle pump is a form of compression pump. Everyone knows that compressed air is used to fill tires. At your garage, tires are filled with air from large tanks of air compressed by a motor driven pump. But when you

have a "flat" on the road, you may have to use a hand pump.

PUPIL ACTIVITY

Observe the diagram of a bicycle pump in Fig. 2-10. Note how it works. Examine a hand pump. Put your finger over the end of the pump, and note at what times the air is expelled and at what times suction is produced. Take the pump apart and notice how the plunger operates in the cylinder. What keeps the air in the tire from escaping back into the cylinder when the pump is working?

Connect the pump to a tire and pump air into it. When a tire gauge registers 15 pounds, how much greater is the pressure on the inside of the tire than on the outside? Why is it more difficult to push the pump handle down as the tube becomes filled with air?

In the bicycle pump a leather washer attached to the piston lets the air flow past in one direction, but not in the other. This washer acts as a valve to let air into the cylinder. The second valve may be in the outlet tube or in the container into which the air is forced, as in an automobile tire.

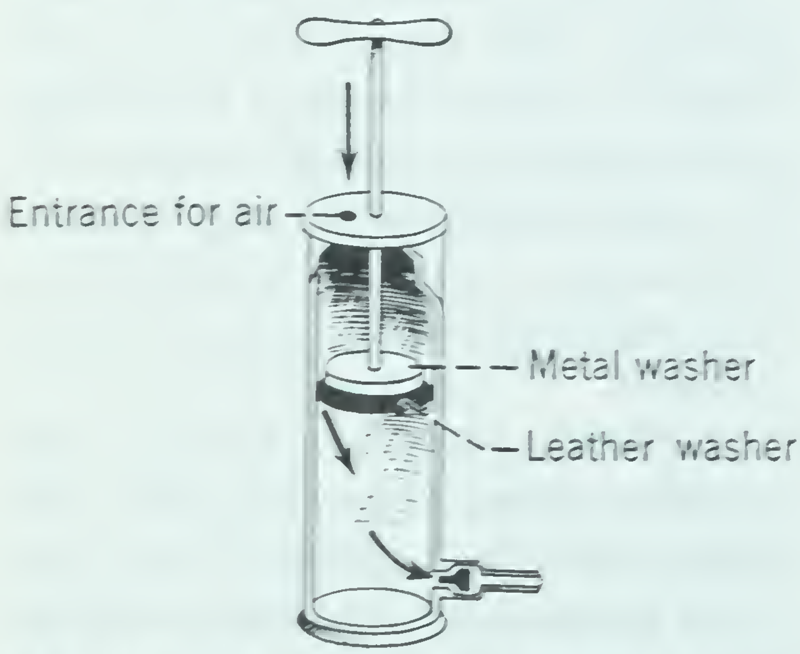


Fig. 2-10. Air is forced out of the cylinder of the pump on each downstroke.

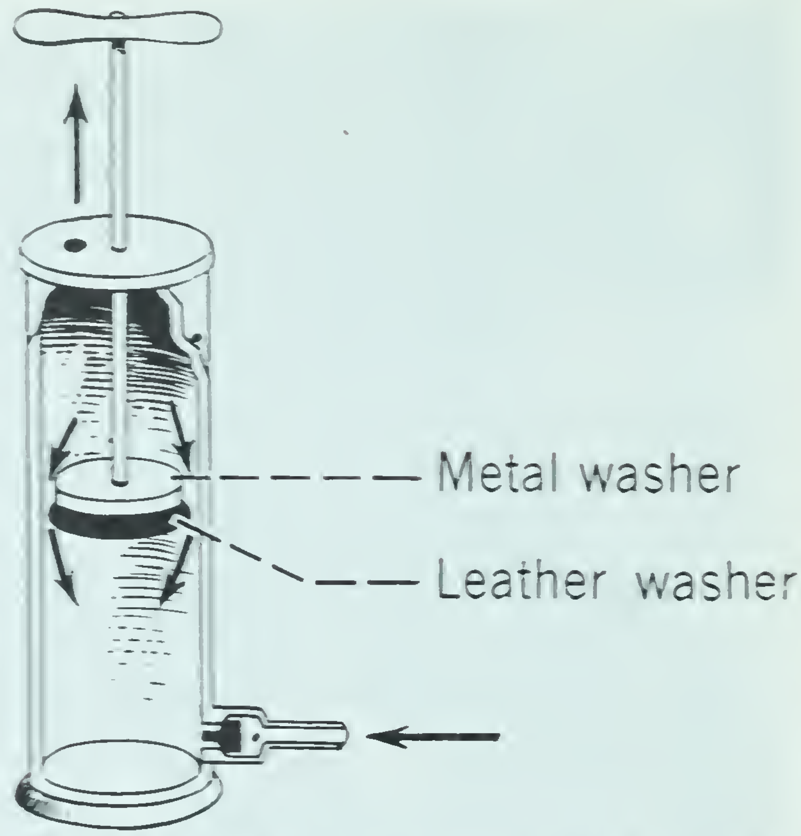


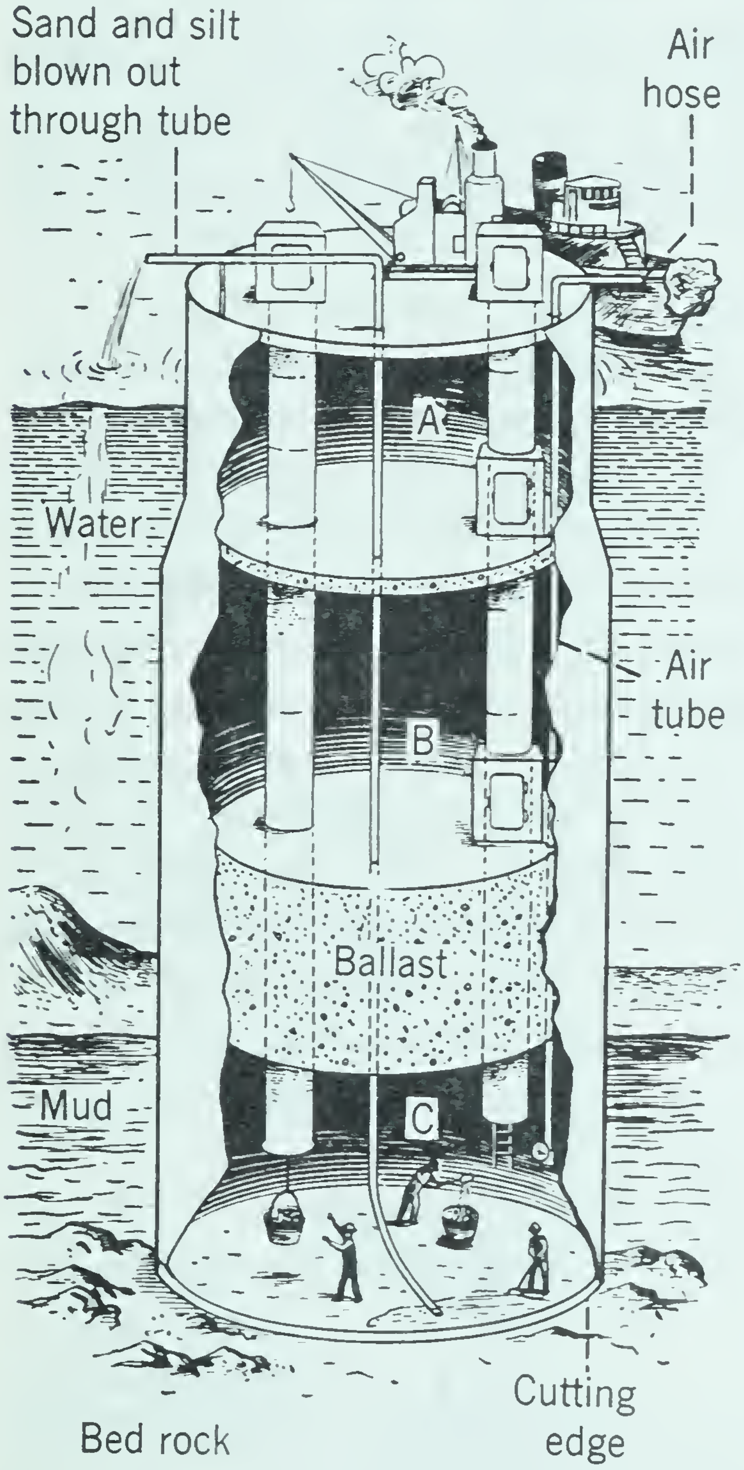
Fig. 2-11. In this pump, air "leaks" past the leather washer of the piston on the upstroke and enters the cylinder.

For each stroke of the bicycle pump more air is pumped into the tire and the pressure increases. The air pumped into the tire cannot escape because its pressure in the tire closes the valve on the upstroke of the pump. It is hard to push the piston down when the pressure in the tire is high. This is because the compressed air in the tire pushes back as the valve in the tire opens.

Other appliances also use compressed air. In building underwater foundations and tunnels, engineers use a *caisson* (*kay*-son), a large chamber, open at the bottom, which is lowered to the bed of the river. Compressed air is forced into the caisson. This pressure on the inside keeps the water from coming into the caisson, so that men can work inside it without getting wet. They can drill through the river bed and make a bridge foundation, or build tunnel walls. When the work is done, the caisson is removed.

Workmen go in and out through large airlocks. Airlocks are very necessary so that the workmen can get used to the high pressure gradually. Figure 2-12 shows a diagram of a caisson.

The long list of other useful devices which use compressed air includes: air guns, riveting machines, drills, spray-



A–	Compressed air 15 lb. per sq. in.
B–	Compressed air 30 lb. per sq. in.
C–	Compressed air 34 lb. per sq. in.

Fig. 2-12. A caisson is weighted so that it will sink through the mud at the bottom. How is the water prevented from entering?

Fig. 2-13. The pneumatic riveter uses compressed air to tighten red-hot rivets which are inserted in their proper place in steel girders. This compressed air enters the riveter through the tube at the left.

ers, door checks, mail and cash tubes, pneumatic tanks for forcing water to the upper stories of houses, tanks used for raising sunken ships, and airbrakes on trains and trucks. Can you think of others? Can you explain how these work?

REVIEW QUESTIONS

1. What is compressed air? **2.** How is it compressed? **3.** Explain how a bicycle pump forces air into a tire. **4.** Name five appliances which depend on compressed air. **5.** How is air compressed for use in service stations?

D How is reduced air pressure used in pneumatic appliances?

Air pressure is reduced in a container when some of the air is removed. Put one end of a long glass tube under water. Now remove the air by sucking at the other end of the tube. The water is pushed up in the tube.

As the air in the tube is removed, fewer molecules are left to produce pressure. Thus the pressure decreases. The outside air pressure, being greater, forces water into the tube until the pressures are equal.

In a medicine dropper, you force out some of the air when you pinch the bulb. When the bulb is released, there is less air than there was. This means fewer molecules and less pressure in the bulb. What happens when the lower end of the dropper is in liquid? The outside air pressure will force the liquid to rise in the dropper to balance the pressures.

PUPIL ACTIVITY

Put the tip of a medicine dropper below the surface of water. (See Fig. 2-14.) Pinch the bulb. What happens? Release the pressure on the bulb. Why is the bulb made of rubber? What pushes the water upward against the force of gravity? Why did you squeeze the bulb? Explain how you created unbalanced air pressure and thus caused natural air pressure to work for you.

An exhaust pump is used to remove air from a container. The construction of an exhaust pump is shown in Fig. 2-15. Part of the air in the bell jar is removed on each stroke of the piston. On the upstroke the air below the piston expands. Valve V_2 is kept closed by its weight and the air pressure above it. Valve V_1 is opened by the pressure in the bell jar. The air continues to flow from the bell jar to the cylinder

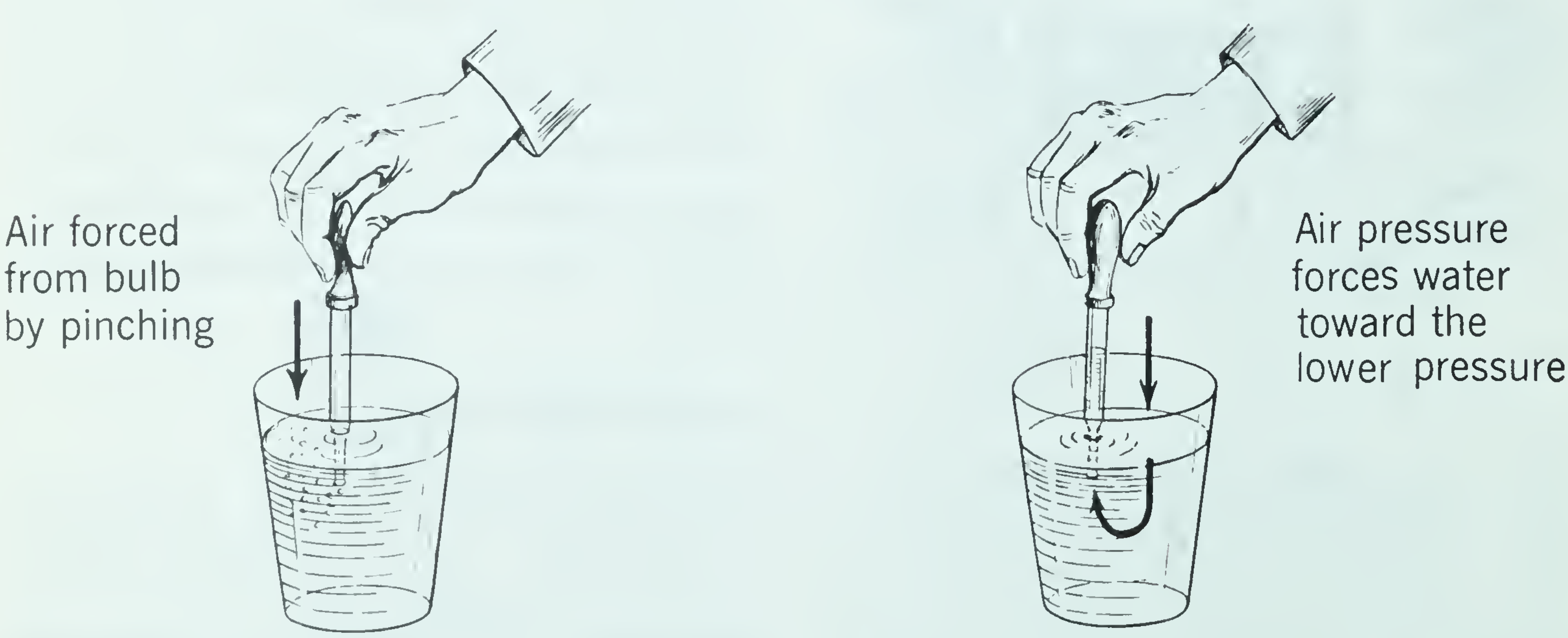


Fig. 2-14. When you release the bulb of a medicine dropper, the water rises in the dropper because a partial vacuum is produced. This principle also applies to the filling of fountain pens.

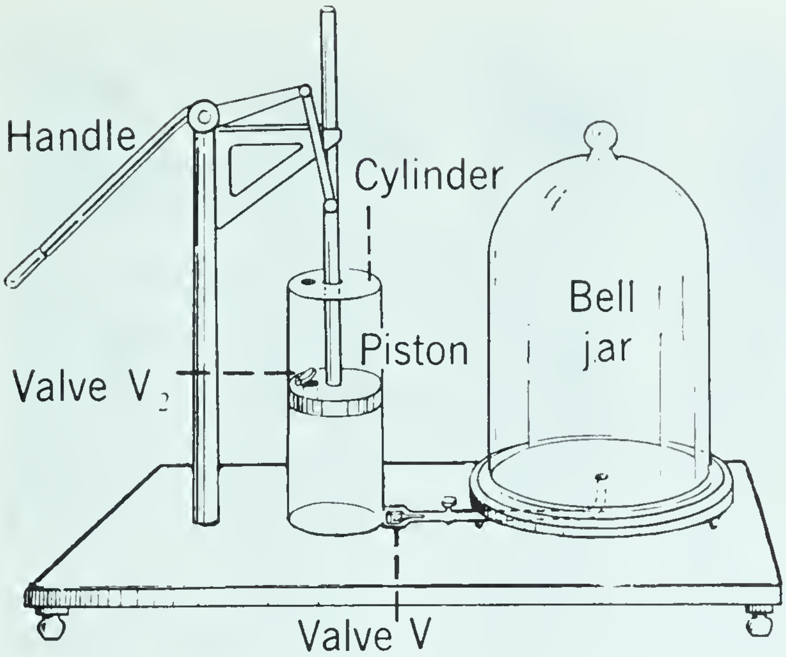


Fig. 2-15. The exhaust pump reduces the air pressure in the bell jar until there is a partial vacuum.

until the pressures are exactly equal.

On the downstroke, the air below the piston is compressed, closing valve V_1 and opening valve V_2. The air in the cylinder flows out through valve V_2. On the next upstroke more air flows from the bell jar to the cylinder and is removed on the downstroke. Each succeeding stroke removes more air from the bell jar. The space in which the pressure is reduced is usually called a *partial vacuum.*

The lift or suction pump creates a partial vacuum. In using these pumps, the unbalanced air pressure which results can then raise water from a well. The two demonstrations which follow will show you how lift pumps work.

DEMONSTRATION

(A) Fill a flask half-full of water. Have two tubes, one long and one short. See that the long tube extends nearly to the bottom of the flask as in Fig. 2-16. Blow into the short tube. Result? Quickly stopper the short tube with your finger. What caused the water to go up the tube? What holds the water up in the tube? Remove your finger. Result? Explain. (B) Blow through the long tube. What are the bubbles in the flask? Stopper the short tube, and blow forcibly through the long tube. Stop blowing, but keep the short tube stoppered. What causes water to go up the long tube? (C) Unstopper the short tube. "Suck" the air out of the long tube as shown in Fig. 2-16. Now what causes the water to rise in the long tube?

DEMONSTRATION

Look at Fig. 2-17, and, if possible, examine a model of a lift pump. Locate the cylinder, piston, piston valve, piston rod, and the lower valve at the bottom of the cylinder.

First stroke: When you lift the piston up in stroke one, what happens to the lower valve C? To the piston valve A? What happens to the air in the pipe?

Second stroke: When you push the

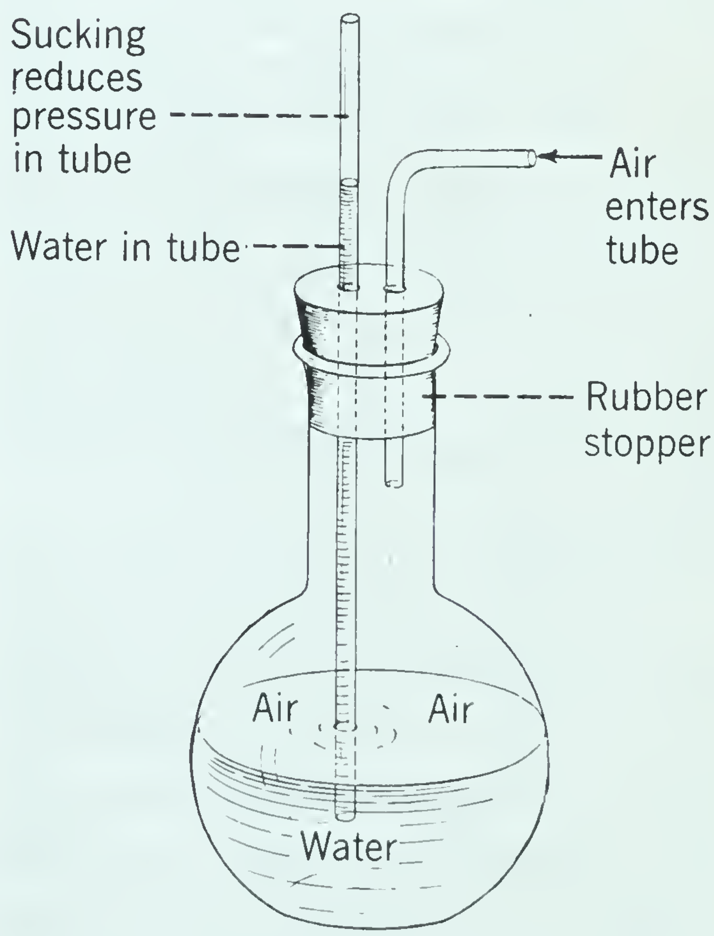


Fig. 2-16. When the air pressure in the tube is reduced, the pressure on the air in the flask forces water up into the tube.

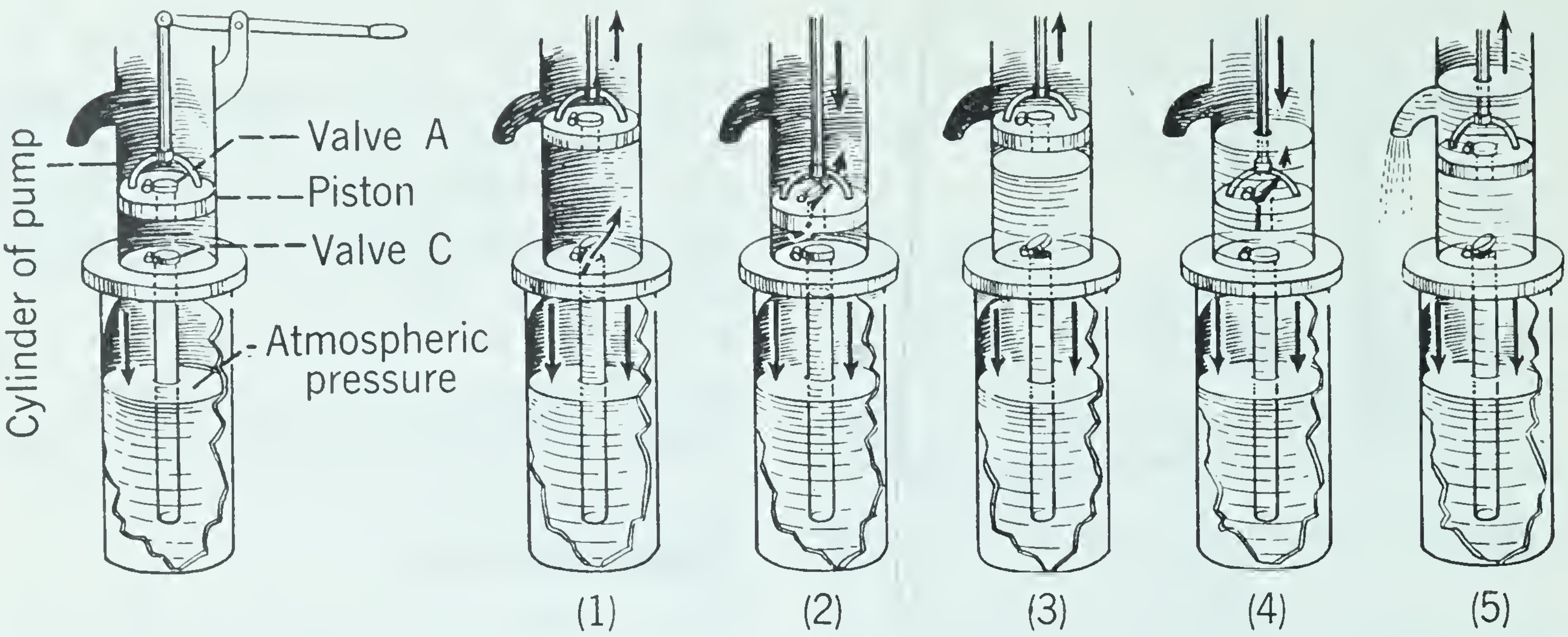


Fig. 2-17. Explain what happens in each of these diagrams of a lift pump.

piston downward, what happens to the piston valve? To the air under the piston? What happens to the lower valve?

Third stroke: What happens to the lower valve when you raise the piston again? To the air above the piston? To the air in the cylinder? What now forces air and water into the cylinder?

Fourth stroke: Force the piston down again. What happens to the lower valve C? To the piston valve A? What causes water to pass through the piston valve? Why is this called a lift pump? Why cannot water be lifted higher than 28 or 30 feet by this method? Why is the piston placed not more than 28 feet above the surface of the water in deep wells? How high could mercury be lifted by the same pump?

The upward movement of the piston in a pump decreases the air pressure in the cylinder of the pump. Then pressure on the water in the well forces water above the lower valve into the pump. The valves should be placed less than 28 feet from the water to get enough pressure for rapid action. On the downward stroke of the piston, the pressure on the water closes the lower valve and opens the upper valve. This lets the water flow above the upper valve, and on the next up stroke the water is lifted by the piston to the spout of the pump.

Often the piston is connected to a long rod of wood or steel. Then the water can be lifted from a well that is more than 28 feet deep. But in all cases, the piston operates within 28 feet or less of the surface of the water.

The force pump is built so that the water is driven out by force. There is no valve in the piston. (See Fig. 2-18.) The second valve B is put at the side of the cylinder of the pump. On the downstroke of the piston, water is forced out through valve B. What closes the lower valve C? How is water forced above valve C on the upstroke of the piston? Can you explain how the air chamber shown in Fig. 2-18 makes the water flow from the pump more evenly?

The siphon operates on a combined gravity and reduced pressure principle. The siphon (*sy*-fon) is shown in Fig. 2-19. It transfers water from one con-

tainer uphill over a small elevation to a lower level. A siphon is used for many purposes, such as emptying an aquarium or a tank, drawing liquids from barrels, and transferring liquids from one container to another. The following demonstration shows how both gravity and air pressure help the siphon work.

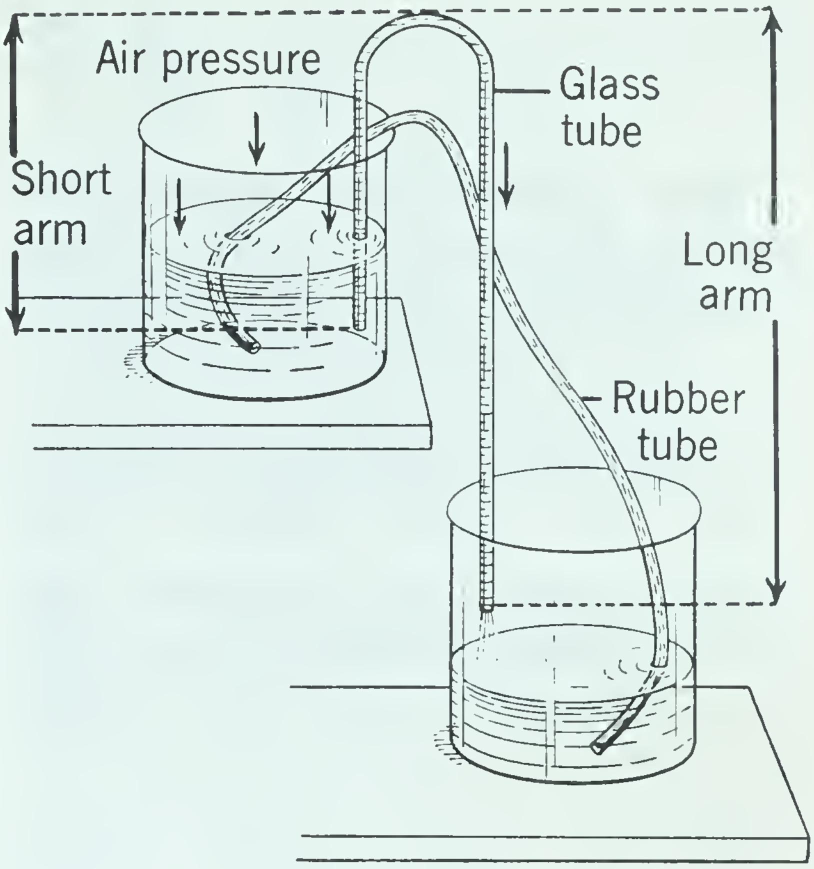


Fig. 2-19. Both gravity and air pressure cause water to flow through a siphon.

DEMONSTRATION

Use about three feet of rubber or glass tubing and fill it with water. Close the ends, invert the tube, put the ends in vessels of water at different levels, and open them. See that one "arm" or side is about twice as tall as the other. Does the water run uphill and then downhill? What presses downward on the water in the higher vessel? What presses downward on the water in the lower vessel? Which arm has the greater weight of water?

Raise the long arm of the siphon slowly until the water stops flowing. How do the lengths of the arms now compare? How do the weights of water in the two arms now compare? When does the siphon stop flowing? Why?

The siphon works because the two arms are different in height. Being different in height, they exert different pressure at the bottoms. The water in the long vertical arm will flow out of the tube.

The removal of the water from the tube tends to develop a partial vacuum in the tube. The air pressure on the water in the upper vessel forces the water up in the short tube, and keeps it filled. The siphon will continue to

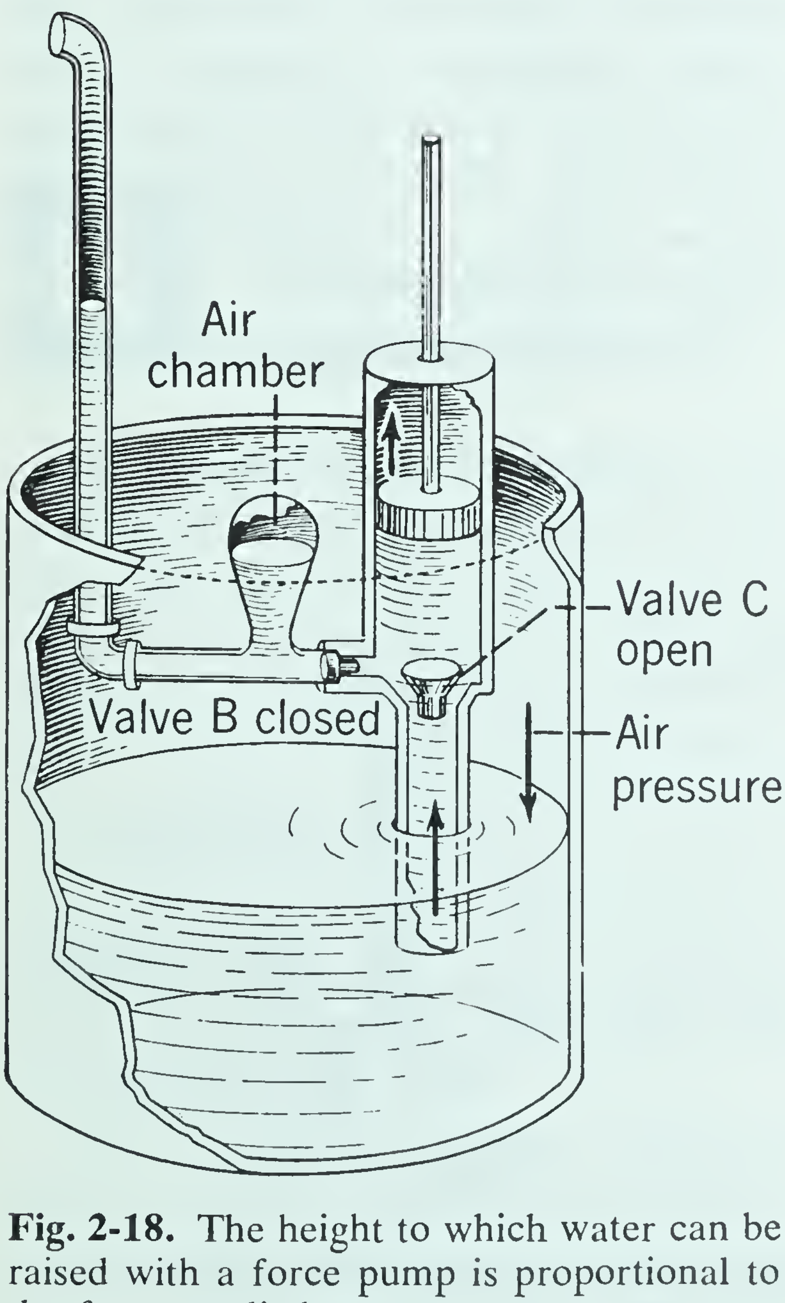


Fig. 2-18. The height to which water can be raised with a force pump is proportional to the force applied.

flow as long as the outlet is lower than the level of the water in the upper vessel.

Some appliances use reduced pressure in an unusual way. They make air or water flow through a small opening or jet. The speed of the water or air is much greater at the narrow opening than the surrounding air. This causes the sidewise pressure of the moving water or air to decrease. The following Pupil Activity will show that causing the air to move more rapidly also causes its sidewise pressure to decrease.

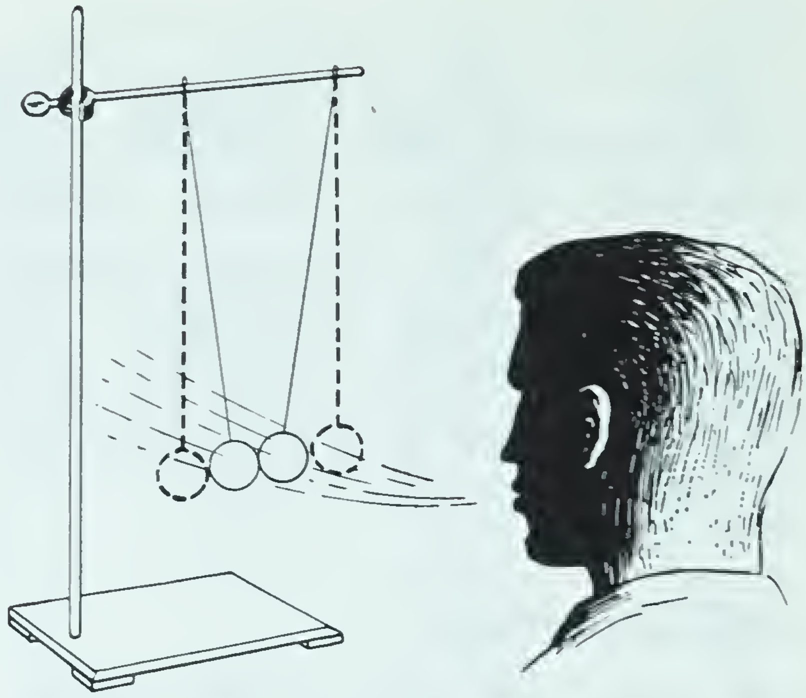


Fig. 2-20. When air is blown between the balls, the pressure is reduced.

PUPIL ACTIVITY

Hang two table-tennis balls about an inch from each other as shown in Fig. 2-20. Blow air between the balls. Result? What is the effect on pressure when air is made to move faster?

An atomizer uses this way of reducing pressure (Fig. 2-21). When the bulb is squeezed, a high-speed stream of air comes out the nozzle. The pressure of this stream is lower than the pressure of the air in the bottle. This means unbalanced pressures, so the air pressure in the bottle forces water up the pipe. When this liquid reaches the air stream, it is broken up into a spray of tiny particles.

The Bunsen burner also uses this

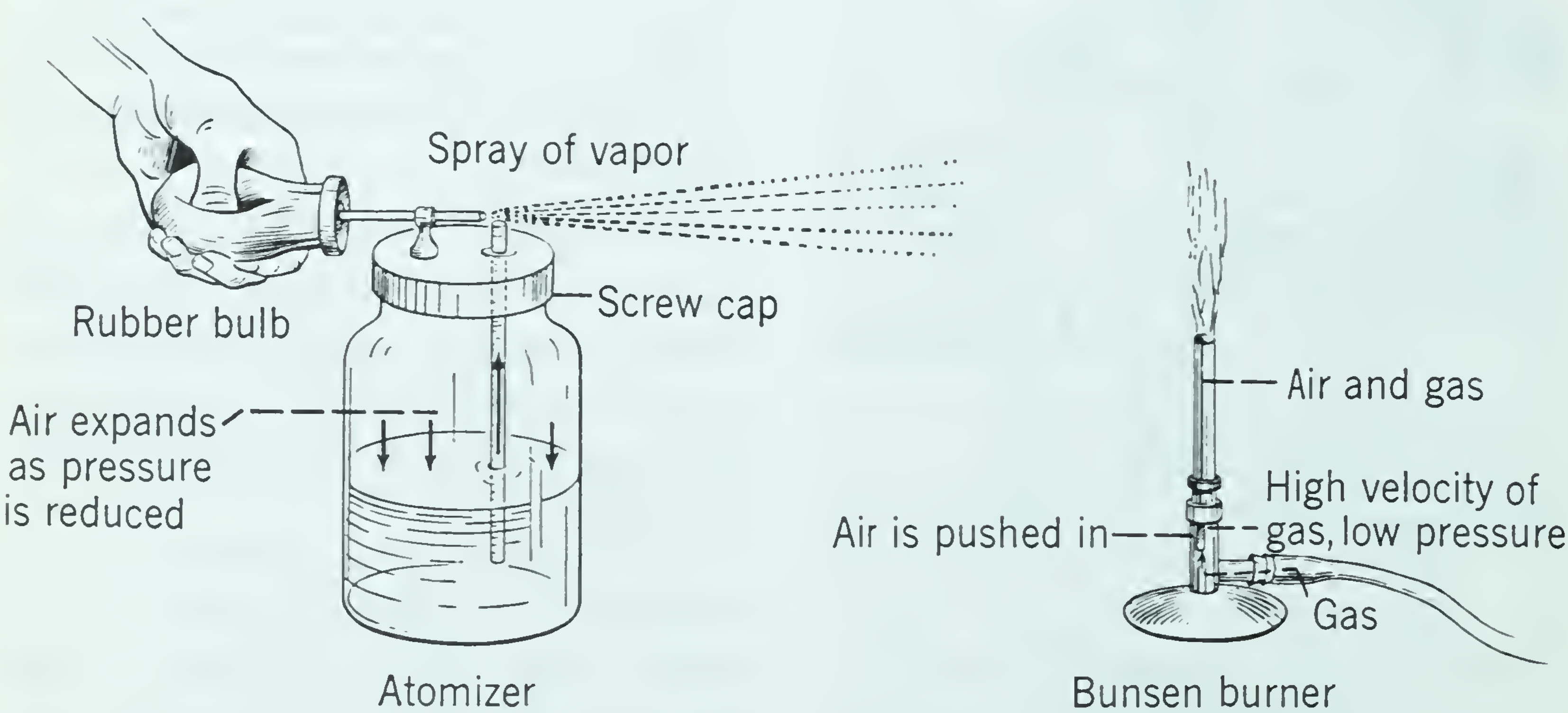


Fig. 2-21. Both the atomizer (left) and the Bunsen burner (right) operate on the principle that pressure can be reduced by increasing the speed of flow of air or water.

way to lower pressure. This time, the gas goes through a small hole and forms a high-speed stream. The pressure of this stream is lower than the air pressure. As a result, air is drawn into the holes.

REVIEW QUESTIONS

1. What type of pump can remove air from a container? **2.** What two types of pumps use unbalanced air pressure to raise water from a depth of 20 to 30 feet? **3.** Explain how the following appliances operate: medicine dropper; soda straw; vacuum cleaner; fountain pen; lift and force pumps; siphon; atomizer; Bunsen burner. **4.** How can water be raised from a well 70 feet deep?

E How does the air hold up balloons?

Air pressure supports balloons. An Arabian scientist first pointed out, in 1137, that air exerts a buoyant force which causes some bodies to float. As long ago as the Middle Ages, men began to wonder if there were not some way of floating vehicles in the air. In 1783, the first balloon was invented. Then two brothers rose 6,000 feet over southern France by using a balloon made of cloth covered with paper, and filled with hot air.

In the same year, Jacques Charles, a French chemist, suggested that hydrogen be used in balloons made of varnished silk. He sent animals up in the balloon baskets and later made flights himself. About 1815, two other Frenchmen went up in a balloon as high as 13,000 feet to study the properties of the upper atmosphere.

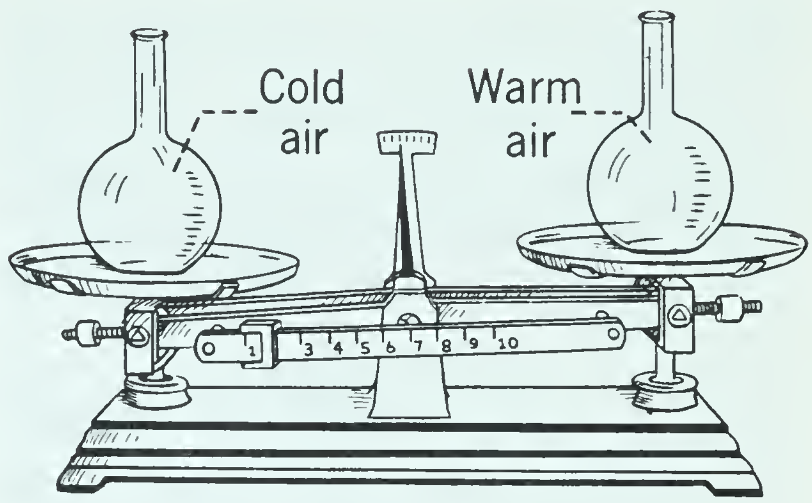


Fig. 2-22. What does this experiment show about the comparative weight of cold air and warm air?

Now let us see why hot air and hydrogen were used to produce the lifting force of the first balloons.

DEMONSTRATION

Select two large flasks of the same size. Put them on the scale and adjust the slider or weights until flasks are balanced (Fig. 2-22). Heat one gradually. Result? How does heating air affect its weight when air is free to expand? Why is cold air heavier than warm air? In which direction will warm air move in a room when the air in it is heated?

DEMONSTRATION

(A) Make a soap solution by dissolving some soap in warm water. Add a few drops of glycerin. Attach a rubber tube to a gas jet and fit a clay pipe into the other end of the tube. Regulate the flow of gas by pressing the tube with your fingers. Blow bubbles with gas. What

makes them float? (B) Hydrogen gas can be made by placing pieces of scrap zinc with acid in a widemouthed bottle. Fit the bottle with a two-hole rubber stopper, which has a piece of bent delivery tubing and a glass funnel tube fitted into it (see Fig. 2-23).

Attach a piece of rubber tubing to the delivery tube and fit the other end to a clay pipe stem. Pour a little dilute sulfuric acid on the zinc. Control the flow of hydrogen gas by the addition of sulfuric acid. Add it slowly! Make bubbles as before. (CAUTION: keep gas at some distance from any flame. Hydrogen gas, when mixed with air, is easily exploded by a spark. Do not kink or stop up the rubber tubing. Sulfuric acid might be forced out of the bottle.)

Hydrogen is the lightest gas we know. It would be the best gas to use in balloons if it did not explode when mixed with air and ignited.

Helium (*hee*-li-um) gas is twice as heavy as hydrogen, but it does not burn or explode. Many other light gases have been used in balloons. In this country helium has replaced the other gases because it is not explosive.

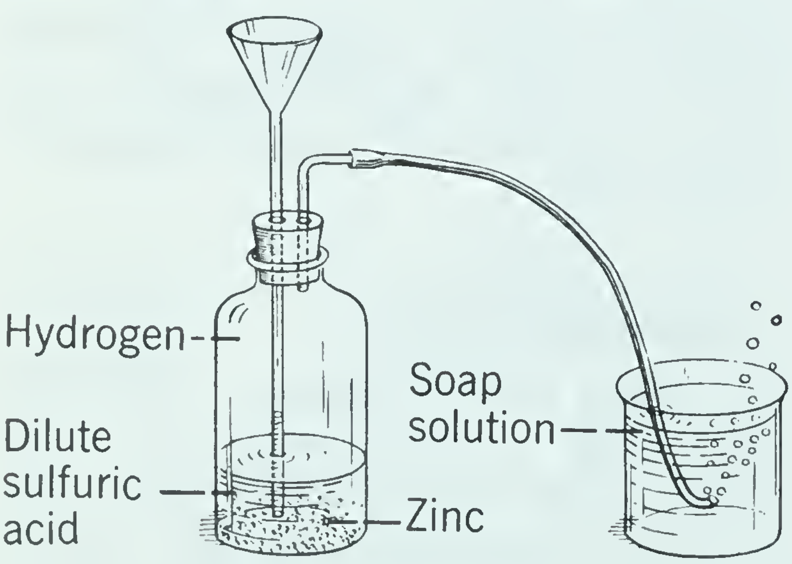


Fig. 2-23. The soap bubbles (in the beaker on the right) are full of hydrogen. What makes them rise?

Fig. 2-24. Explain why this balloon rises.

A balloon rises because air has buoyancy. Air, like water, has the ability to support objects and make them float. This ability is called ***buoyancy.*** A balloon in air is pulled downward by gravity and pushed upward by buoyancy. When these two forces are just equal, the balloon floats. When the upward force is greater, the balloon rises. When the downward force is greater, the balloon sinks. The downward force is the weight of the balloon and gas. The upward force is equal to the weight of an amount of air that has the same size as the balloon and gas. This amount of air is called the *displaced air.*

The net lifting force of air on a balloon equals the weight of the displaced air minus the weight of the balloon and the gas. If a balloon is to have much lifting force, it must have a

large volume. This is so it will displace a large volume of air. The upward force, remember, is equal to the weight of this displaced air (see Fig. 2-25). Materials used in making and filling the balloon should also be light, so the pull of gravity on them will not be great.

A man in a balloon can change the size of the gas bag and thereby make it rise or fall while in the air. If he lets gas out, the balloon gets smaller, displaces less air, and therefore sinks. But he does not put in more gas to make the balloon rise. Instead, he throws out some sand or lead dust which he is carrying in bags as ballast. The balloon rises then because the same sized balloon is carrying a lighter load than before.

When a balloon first starts to rise, the pressure of the gas on the inside is equal to the pressure of air on the outside. As the balloon gains altitude, the outside air pressure decreases. Then the gas in the balloon has a greater pressure, and it forces the balloon to expand. The balloon is only partly filled with gas on the ground so that it can expand at higher altitudes.

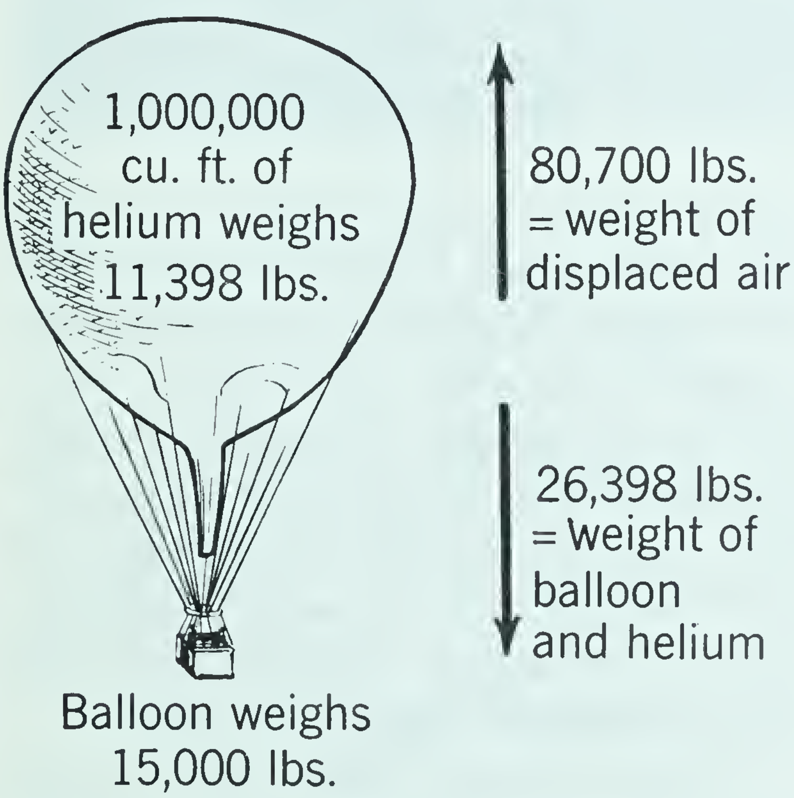


Fig. 2-25. This balloon could lift an additional 54,302 pounds. Explain why.

REVIEW QUESTIONS

1. What do we mean by the buoyancy of air? **2.** What causes balloons to rise? **3.** How may balloons be made to descend? **4.** Why is ballast carried in a balloon? **5.** Give one reason why hydrogen is a better gas to use in a balloon than helium. **6.** Why is helium, rather than hydrogen, used in modern balloons? **7.** Why does a toy balloon, blown up with air, not float or rise? Use the idea of lifting force in your answer.

F How has man learned to apply the principles of air pressure to airplanes?

An airplane is similar to a kite. A thousand years before man invented an airplane that would fly, the Chinese had invented the kite. Later, the principle of the kite was used in making an airplane. Men knew that a kite stayed up in the air, held by the force of the wind. But a machine like an airplane had to have an engine. The reason was that the engine would drive the airplane through quiet air at the same speed as wind. A toy led Wilbur and Orville Wright to invent the airplane. Their father gave them a toy machine with propellers at each end, whirled by

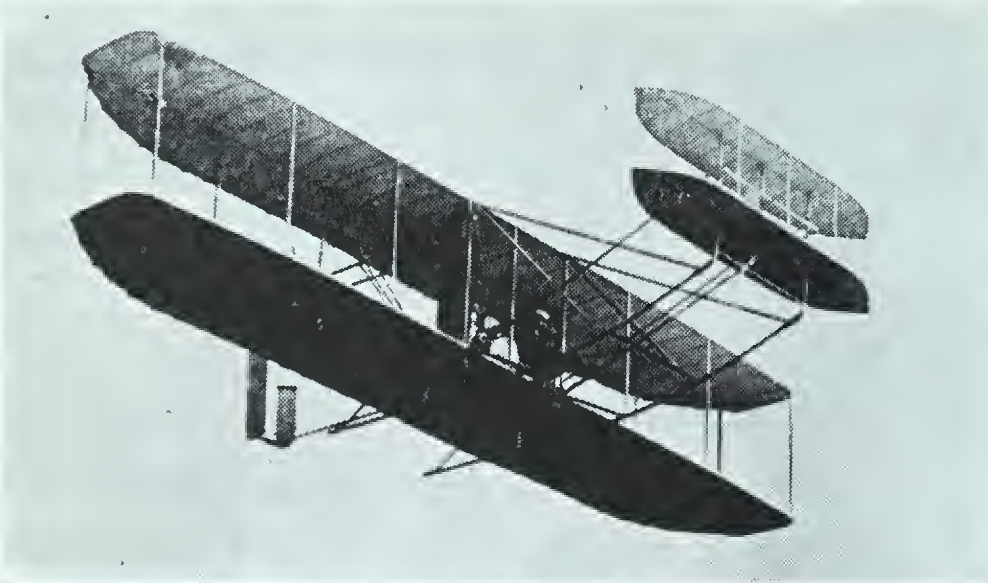


Fig. 2-26. There is quite a difference between the Wright Brothers' first plane and a modern airplane. Both are products of scientific discoveries and careful research and testing.

a rubber band. The boys called it a "bat" and it really could fly. This set them wondering if they could not build a full-sized flying machine.

About this same time, a German scientist experimented with a glider. He was killed trying to make it work. His death made the Wrights try harder. They read everything they could find on kites and gliders, and kept on experimenting.

They first built a biplane glider which they took to the sand dunes at Kitty Hawk, North Carolina. At first, they flew it like a kite. Then they got into the glider and learned how to balance it in the air.

They finally put a gasoline engine in the glider and fitted a pair of propellers to it. On December 17, 1903, Orville Wright took a seat in the plane, started the engine, and made the first human airplane flight in history.

Orville's flight lasted only 12 seconds, but it proved that the airplane was a practical possibility. The

Wright's fourth flight lasted 59 seconds, and in that time their machine traveled a distance of 852 feet.

We can learn much about the airplane from studying the kite. A kite is held against the wind by a string. The wind tends to blow the kite away and the string holds it back. The airplane is pulled against the air by a propeller. The same effect of wind is produced, but the plane is moving while the air is still. When you fly a kite, you notice that part of the wind presses against the kite, but most of the air rushes past it. Does some of the air tend to push the kite backward? How does the kite's inertia help to hold the kite up?

When the wind rushes past the kite, the air that goes below the surface is slightly compressed as shown in Fig. 2-27, while a partial vacuum is created above. The air below the surface then has an increased pressure. This pushes the kite up. The kite is also pushed up into the partial vacuum above the kite.

An airplane is heavier than air. When it is at rest on the ground, it is held there by the force of *gravity*. Gravity is a downward force that acts on an airplane in flight as well as on the ground.

If the airplane is to be lifted off the ground, an upward force greater than the force of gravity must be applied. This upward force, which acts on an airplane only during flight, is called the *lift*. How is this lift produced?

DEMONSTRATION

Hold a piece of paper as shown in Fig. 2-28(A). Blow across the upper surface of the paper. Result? Now hold the paper in the same position and blow against the under side as shown in Fig. 2-28(B). Result?

From this experiment we can see that the lift of the wing is caused by the air moving across the upper and lower surfaces of the wing. About two-thirds of the lift is produced by the reduced pressure of the air above the wing. The other third comes from the force of the moving air against the lower surface of the wing.

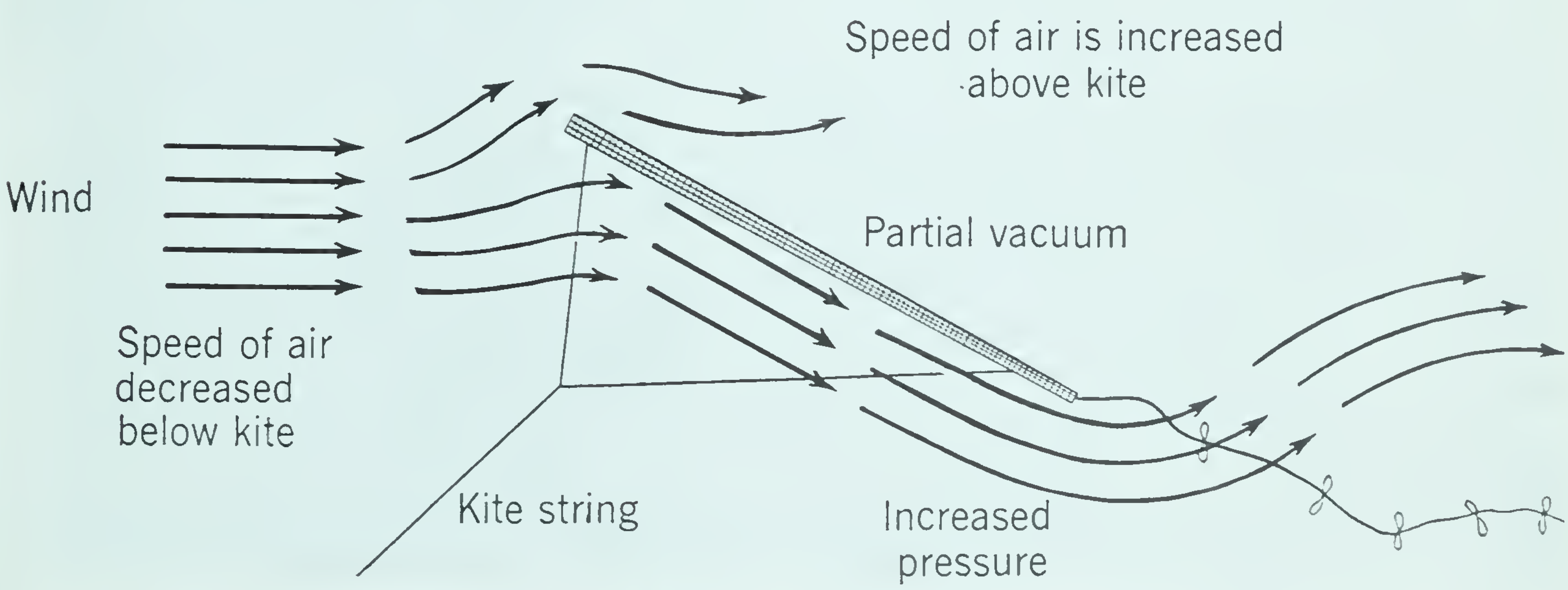


Fig. 2-27. A partial vacuum is produced above the kite by the wind. How is an airplane similar to a kite?

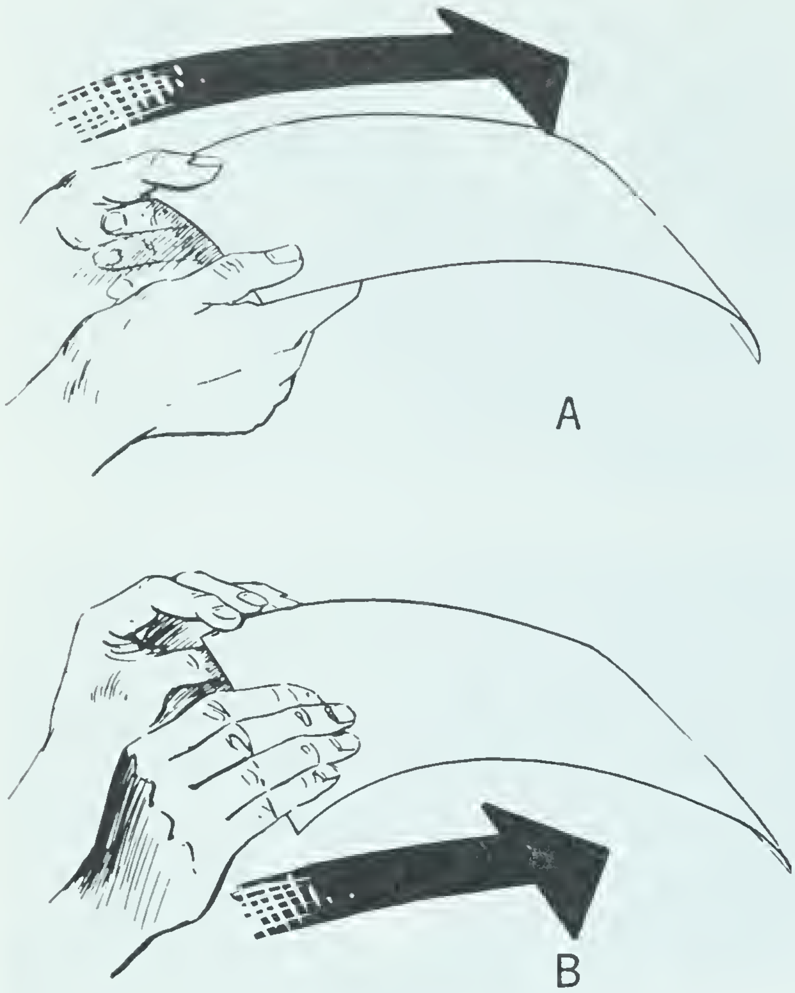


Fig. 2-28. The above experiment shows you how the lift is produced in a plane.

Helicopters are built differently from other airplanes. Instead of ordinary wings, a helicopter has one or more sets of rotating blades which whirl through the air like a windmill. The horizontal whirling blades produce lift just as the wings of airplanes do. Since the "wing" of the helicopter is already moving through the air, this type of aircraft does not require a long runway. It can take off vertically from a small space and also land vertically in the same small space.

The helicopter can fly very slowly and even hover over one spot. Because of this helicopters are used for many purposes for which other airplanes are unsuitable.

Many airplanes are driven by propellers. If you examine an airplane propeller you will see that it has curved surfaces similar to those of the wing. As the propeller spins it pushes air backward and thus produces a forward pull. This force is called ***thrust.***

DEMONSTRATION

Put a few round pencils under an electric fan as shown in Fig. 2-29. Now turn on the fan. Result?

The fan blows air in one direction and thus is forced to move in the opposite direction. In the ordinary type of airplane the force to spin the propeller is produced by a gasoline engine.

The jet propelled plane does not need a propeller. All the thrust is produced by the force of unequal pressures in the explosion chamber. In this explosion chamber, gases are produced under high pressure by the burning of the fuel, and by using a compression apparatus.

The force exerted by the high compression gases is the same in all directions. The light gases at the back opening are pushed backward at high

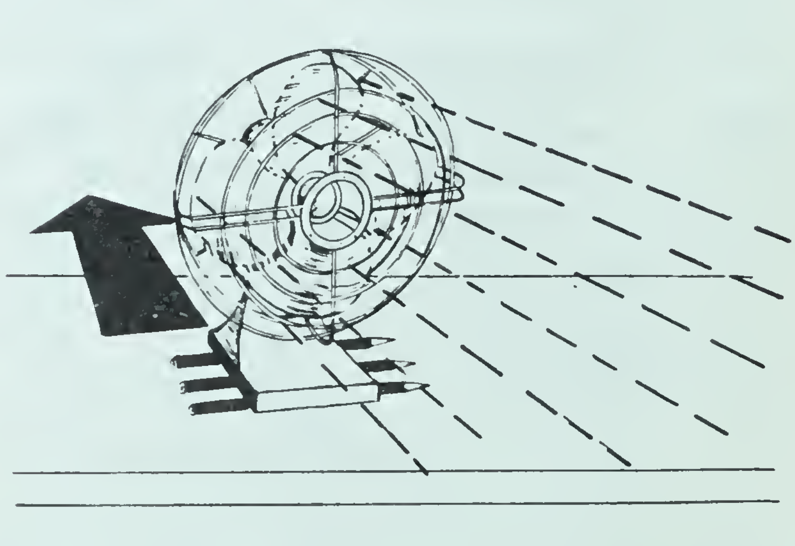


Fig. 2-29. What force is illustrated here? How is this force produced in a plane?

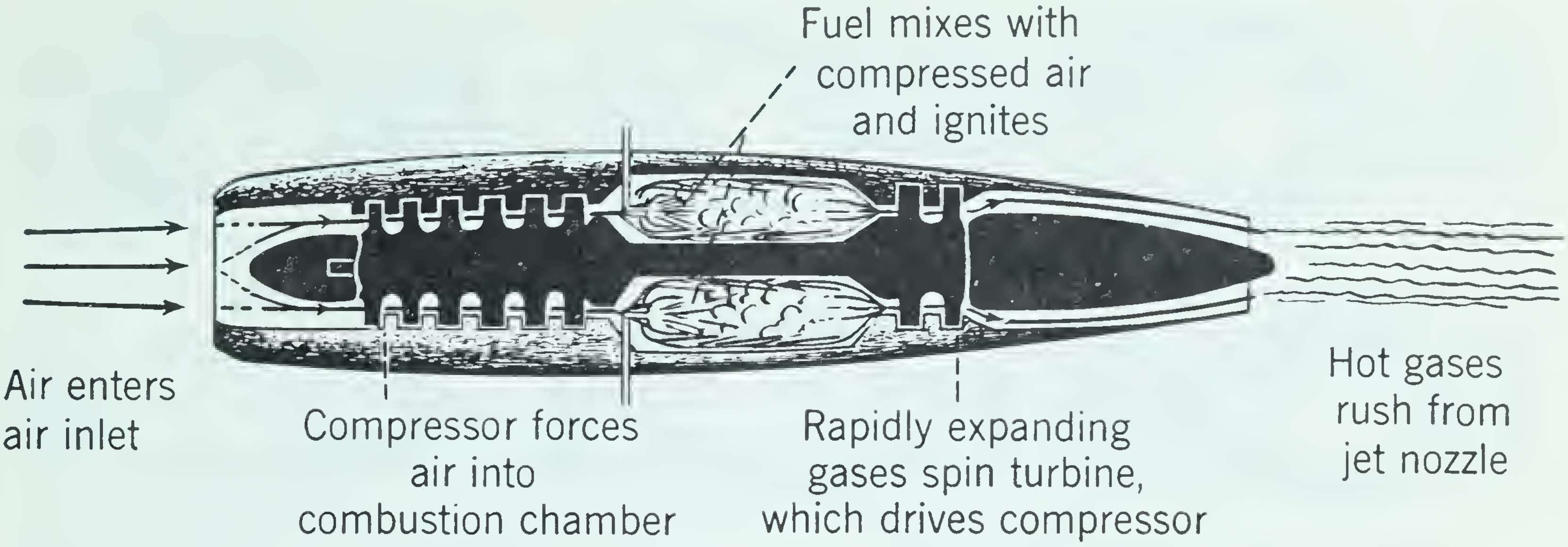


Fig. 2-30. The above diagram shows the combustion chamber of a jet engine.

speed, and at the same time, the solid part of the chamber at the front is pushed forward, but at a lesser speed. It is this force that produces the thrust of a jet engine.

DEMONSTRATION

Inflate an ordinary rubber balloon and then pinch it shut with your finger. Hold it up high and release it. Result?

This method of producing thrust is called *jet propulsion.* The common jet engine, (Fig. 2-30), takes in air, compresses it, and then burns its fuel rapidly in the compressed air. This produces large volumes of hot gases whose expansion produces tremendous thrust.

Rocket engines produce another type of jet propulsion. A rocket carries both its fuel and the oxygen required to burn it. The rocket principle is used in all guns that rely on explosives. A shotgun shell, for example, contains an explosive which has chemicals in it

Fig. 2-31. A modern jet plane can reach a speed of well over 600 miles an hour. Why does it not need a propeller?

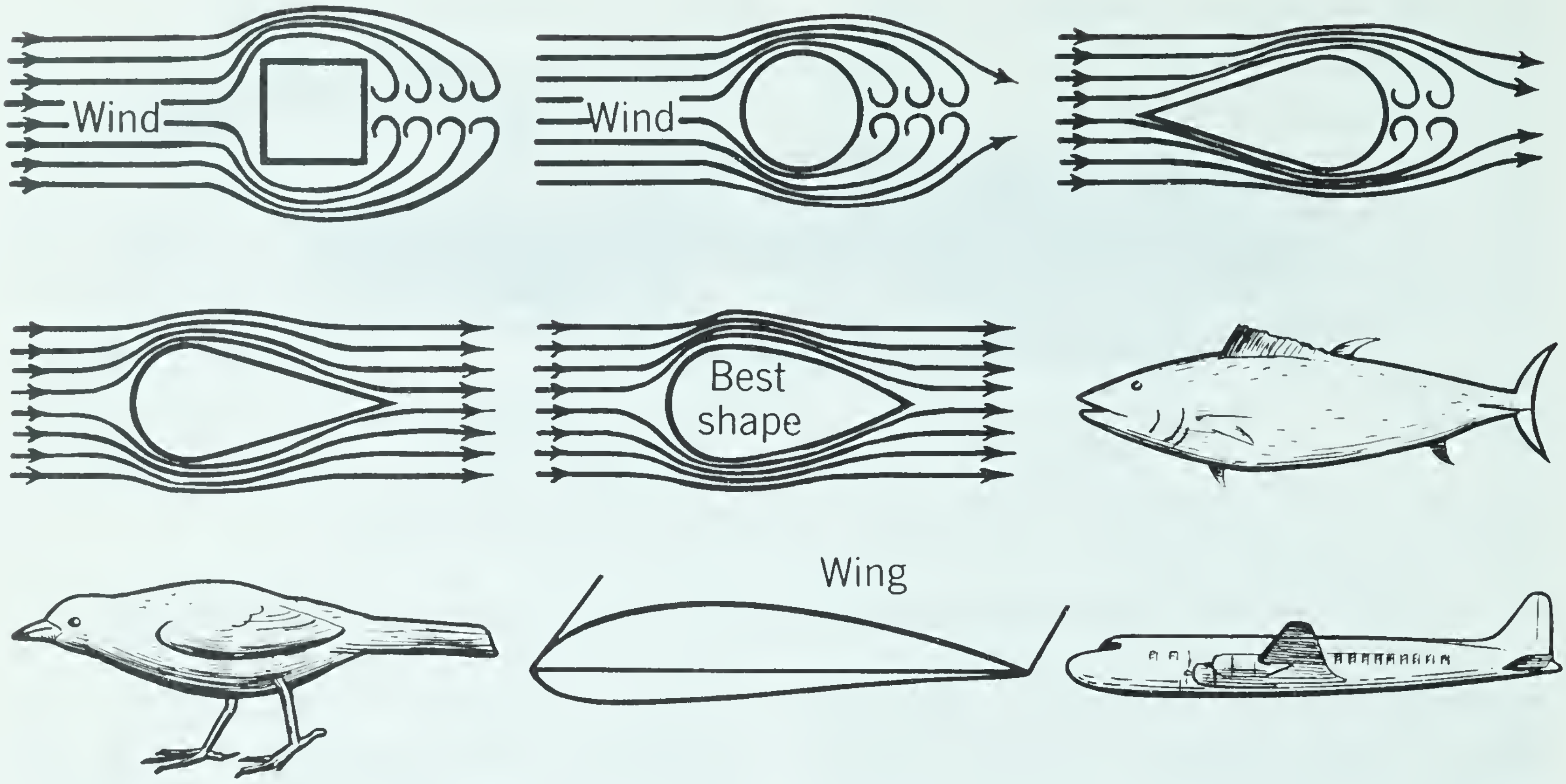


Fig. 2-32. From the above diagrams, note how the shape of an object affects the flow of air around it.

that furnish both fuel and oxygen. You might compare the "kick" of a discharged shotgun to the thrust of a rocket engine.

A rocket engine could be used outside the earth's atmosphere. This is because it does not require air as the common jet engine does. Rockets are now used to drive experimental aircraft and guided missiles of various types. It is probable that rockets will be used to propel space ships when they are produced.

Streamlining is important in airplanes. When an airplane is in motion, air flows around all its exposed surfaces. This produces friction which tends to retard its forward motion. The shape of the airplane is also important. Study Fig. 2-32 to see how the shape of an object affects the flow of air around it.

The resistance caused by friction and air flowing around the airplane is called ***drag.*** It can be reduced by streamlining the airplane and by giving the plane a smooth coating on the outside. Compare the photographs in Fig. 2-26 to see the advances that have been made in streamlining airplanes.

Four forces act on an airplane in flight. We can now summarize the forces that act on a flying airplane. *Gravity* tends to pull the plane toward the earth. This force, equal to the weight of the plane, is balanced by the

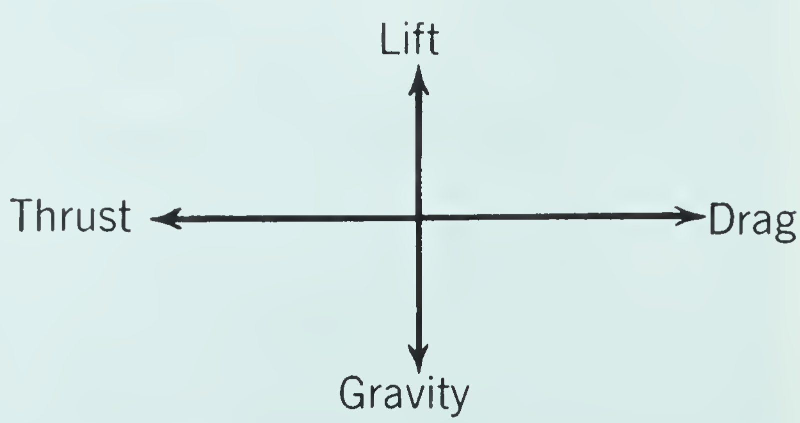


Fig. 2-33. These four forces act on an airplane in flight. For an airplane to fly level, these four forces must all be in balance.

lift of the wings and other surfaces. The *thrust* of the propeller or jet drives the plane forward, while *drag* tends to slow it down.

When these forces are all in balance, the airplane flies level at a steady speed. To gain altitude there must be an increase in lift. To gain speed, there must be an increase in thrust. The force of gravity does not vary much at different altitudes. Drag is increased greatly with added speed. It is reduced considerably at high altitudes. Why?

The pilot controls the flight of the airplane. To control the airplane in flight, the pilot must be able to change its speed and direction. Speed is regulated by a throttle which feeds fuel to the engine. This works very much like the gas pedal on an automobile.

The control of direction is more complicated in an airplane than it is in an automobile. To turn it from right to left, the airplane has a *rudder* which acts in the air as a ship's rudder acts in water. The rudder is turned by foot pedals in small planes and by a wheel in larger ones.

In order to gain or lose altitude the plane has ***elevators***, usually at the tail. When the elevators are raised, the plane is tilted upward so that it climbs, and when the elevators are lowered, the plane is tilted downward to lose altitude.

The ***ailerons*** are usually located at the rear edges of the wing. They are built in such a way that one rises as the other is lowered. Thus the plane can be made to bank or roll by changing the position of the ailerons.

In light planes, both the ailerons and elevators are controlled by a ***stick*** set in the floor of the cockpit. Forward motion of the stick causes the plane to dive, while backward motion makes it rise. If the stick is moved to the right, it rolls the plane to the right by raising the right aileron, and lowering the left one. Opposite motion of the stick pro-

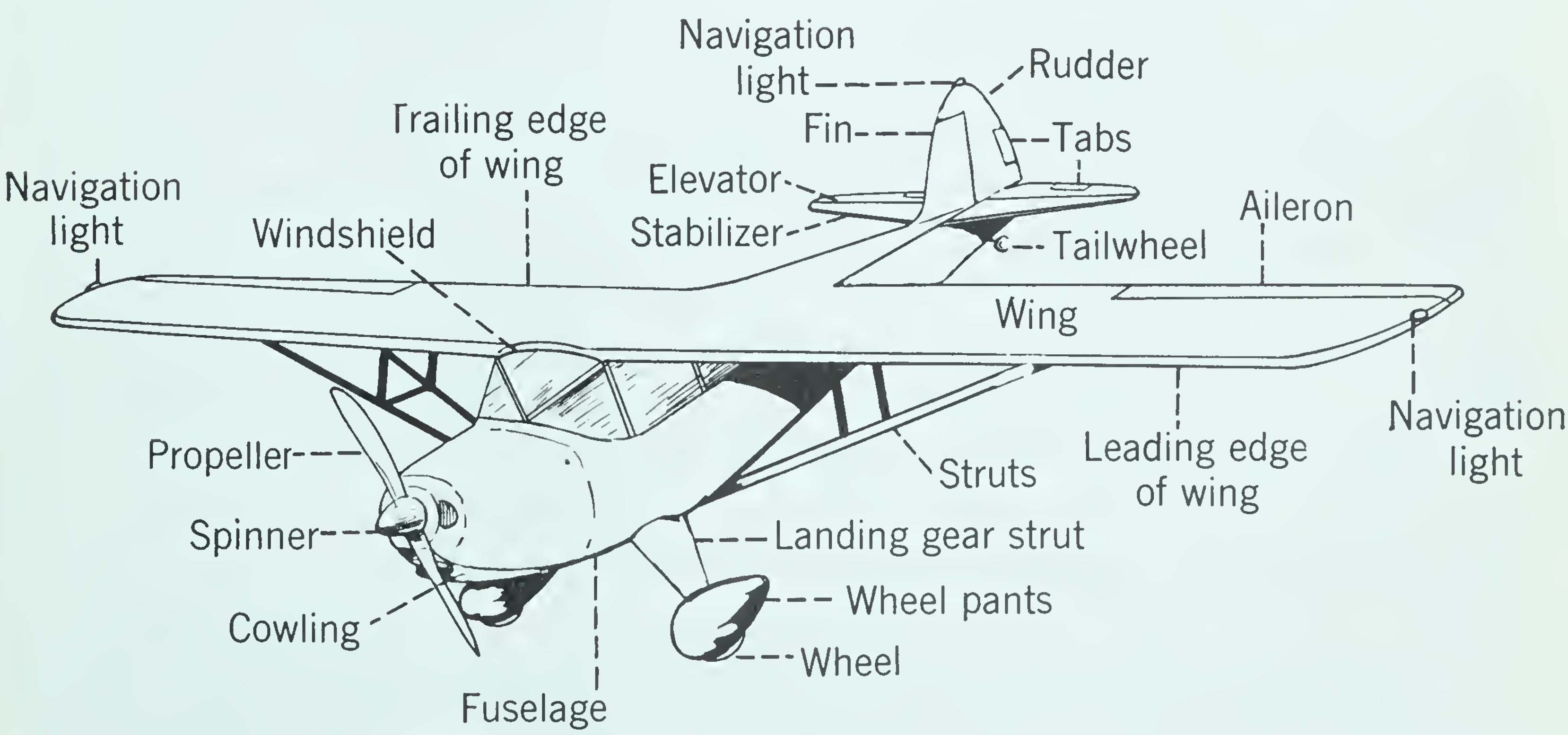


Fig. 2-34. The parts of a typical monoplane are shown here.

duces a roll to the left. In large planes ailerons, rudder, and elevators are all controlled by a *wheel* which can be pushed forward or backward, and also turned from right to left.

The elevators, rudders, and ailerons together are known as *control surfaces.* By changing their positions the pilot can make the plane fly in whatever direction he wishes.

REVIEW QUESTIONS

1. What keeps a kite in the air? **2.** What are the four forces acting on an airplane in flight? **3.** How is lift produced? **4.** How does streamlining reduce drag? **5.** How should an object be shaped to meet with the least air resistance? **6.** How is a pilot able to control an airplane in flight? **7.** How is a jet-propelled plane different from one driven by propellers?

QUESTIONS FOR REVIEW AND DISCUSSION

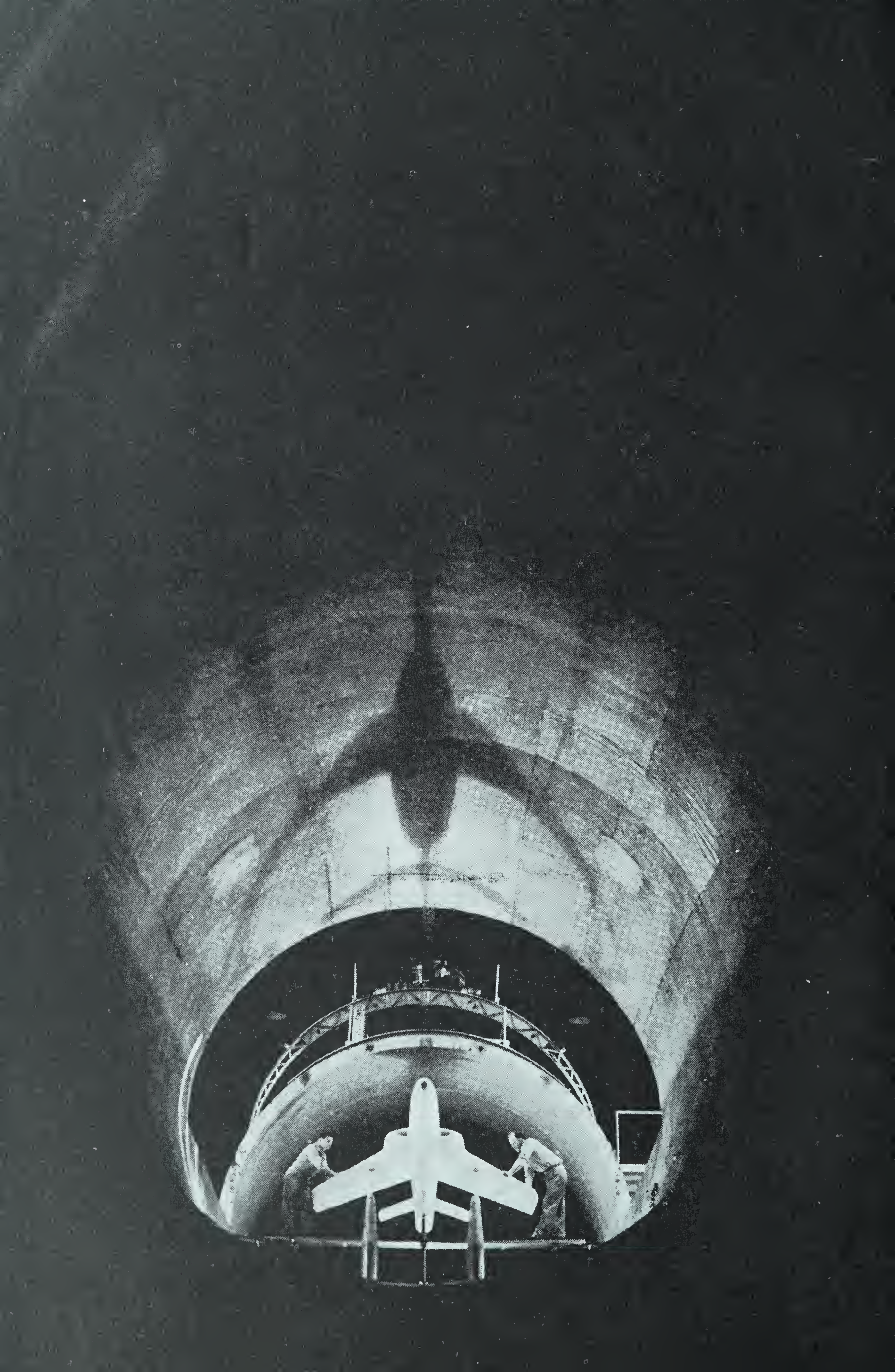
1. What idea did the ancient people have about the nature of air? What use did they make of this idea?
2. Why did Galileo and Torricelli construct the barometer? What was the problem they were trying to solve?
3. In what different ways can the pressure of air be changed?
4. How do we know that small particles of air exist even though we cannot see them under a microscope?
5. What makes a football bounce when it hits the ground?
6. Why should you make two holes in an oil can when pouring from it?
7. What is the weight of one cubic foot of air at normal pressure?
8. How does the barometer measure air pressure?
9. What is the normal pressure of air in pounds per square inch?
10. What do we mean by unbalanced air pressures?
11. What is a vacuum? A partial vacuum?
12. What is compressed air, and how is it compressed?
13. What causes balloons to rise in air? How long will they go on rising?
14. Figure out which way an airplane's elevators should be moved to cause it to climb. (Both elevators move in the same direction.)
15. Why are modern automobiles and trains streamlined?
16. What causes an airplane to move forward through the air?
17. How do each of the following devices operate: soda straw; atomizer; medicine dropper; siphon; Bunsen burner; lift pump; force pump; bicycle pump; vacuum cleaner; barometer; air brake; caisson? (To explain how a device operates, tell how it is constructed, and how and why it operates as it does.

SPECIAL REPORTS AND PROBLEMS

1. Make a kite and explain how you would fly it.
2. Make a toy windmill and explain what makes it go.
3. Explain how a fountain pen operates.
4. Make a siphon and explain how it operates.
5. Study a vacuum cleaner and tell how it operates.
6. How does a paint spraying machine work?
7. Explain how the jet airplane moves forward.
8. Report on the history of the barometer.
9. Report on the history of jet propulsion.
10. The development of rocket planes and missiles.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: pressure, air pressure, molecules, compressed air, vacuum, altimeter, buoyancy, lift, thrust. drag, elevators, ailerons, streamlining?
2. In what ways have the following pieces of apparatus helped man: barometer, exhaust air pump, air compression pump, and water pump?
3. How has the airplane changed man's activities?
4. How does a knowledge of molecules help to explain air pressure?
5. Would you expect an invention made scientifically to be better than one that depended on luck? Were the Wright brothers scientists?
6. Compare a glider and a kite.
7. How are wind tunnels used to help improve the airplane?
8. The rate of flow of liquids through a siphon is affected by the following factors: (a) difference in the heights of the two arms, (b) diameter of the tube, and (c) nature of the liquid. Plan a controlled experiment to measure the effect of each of these factors on the rate of flow through a siphon. Perform the experiment as planned. State the conclusions for each factor.
9. In turning a curve with an automobile, the friction of the tires on the road keeps it from slipping toward the outside. What is done to prevent the airplane from "slipping" in the air when its direction is changed? Consider the use of the rudder and the ailerons.
10. What is the position of the elevators when the plane is ascending? When descending?
11. Why can jet planes travel at greater speeds than planes with propellers?
12. Suppose that jet-propelled airplanes took the place of all propeller-driven airplanes. How might this affect your daily life?



The old

AS LONG AS THE WORLD HAS BEEN IN EXISTENCE, THERE HAVE been gases around it which make up what we call its air. People have to breathe air to live. It has to be not only in their bodies, but all about them. They feel its pressure; they are aware of its motion; they know its force. They make use of its force to move their sailboats forward. And the urge to fly is as old as man himself.

Gradually scientists learned by experiments that air is a real substance, that it has weight, that it exerts pressure, and that it can be compressed. They learned that air has inertia. It offers resistance to being moved. This knowledge of the air made possible the invention of instruments to measure air pressure and pumps to compress it.

The new

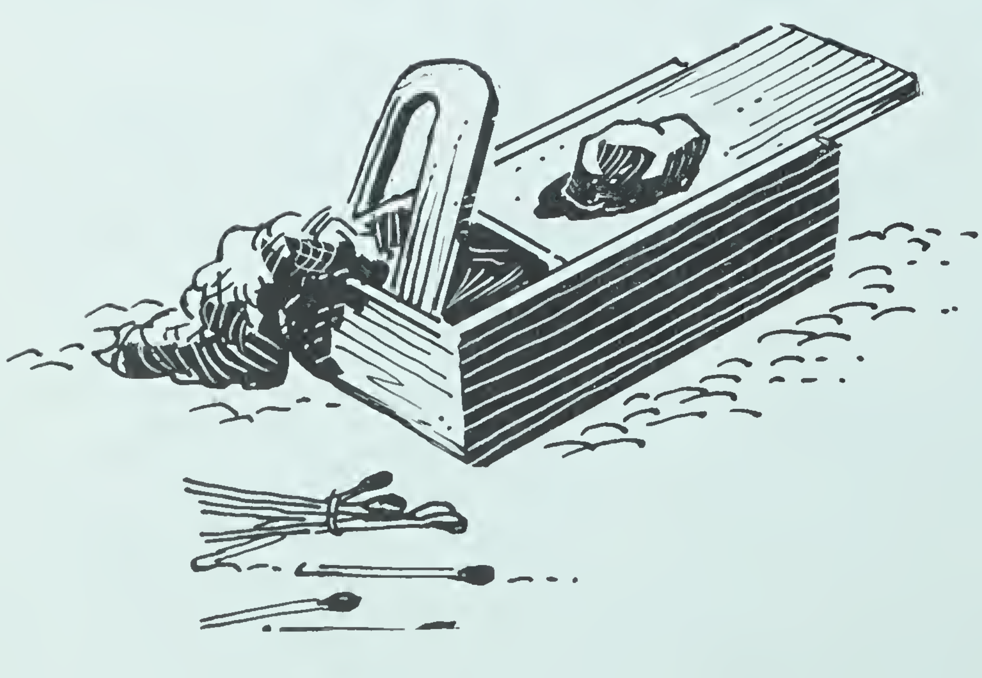
MODERN APPLICATIONS OF THIS KNOWLEDGE HAVE MADE possible pneumatic tires, air engines, blast furnaces, air riveters, compressed-air engines, vacuum tanks, balloons, dirigibles, airplanes, and many other appliances.

In the past few years, advances have been made in the building of airplanes which will carry heavy loads, travel great distances, and travel at speeds of over 1,000 miles an hour. Planes have been built also which, with a supply of oxygen to burn the fuel, will fly successfully at high altitudes. Extra oxygen is supplied to the crew and passengers for breathing comfort.

A fundamental principle of science has been applied in the jet-propelled engine. Rapid burning in the engine develops the force for propulsion. There are no moving pistons and the engine has very few moving parts. As far as engine operation is concerned, jet-propelled planes can fly in the upper atmosphere as well as near the ground. The photograph on the facing page shows a model of a new jet airplane being made ready for testing in a modern wind tunnel.

Probably jet engines will soon be used in automobiles, trains, and for many other machines. They will operate on cheaper fuels and with higher efficiency than ordinary gas engines.

Rocket engines are now used to propel aircraft and guided missiles. Interplanetary travel may be possible in the future when rocket-powered space ships are built.



How has man learned the nature and uses of fire?

UNIT 3

DISCOVERY AND PROGRESS

THERE probably was never a time when the world was without fire. The earliest fires were started in forests by lightning or by volcanoes. But thousands of years passed before man learned how to make a fire. He made little progress until he learned how to make one himself. But from that time on, his shelters had both heat and light. His food was cooked and savage animals were scared away. He could even make metal weapons and tools. Civilization began with man's control of fire.

The early Indians knew how to make and use fire. Their method was to turn a round stick of wood rapidly in a hollow place in another piece of wood. The friction of the two pieces of wood rubbing against each other made enough heat to start a fire in dry leaves, shredded bark, or tinder. Boy Scouts sometimes use this method today. Perhaps you have used it yourself. The South and Central American Indians used a curved polished mirror made of metal that concentrated the rays of the sun to produce fire.

Later someone found that he could make a spark by striking one hard stone against another. In pioneer days, the tinder box proved to be an effective device in starting fires. This appears in the panel facing page 59. In this were a piece of flint and steel. The steel was struck against the flint with a rubbing motion, and the sparks fell into the tinder box, which was filled with bits of cotton and scorched linen yarn. The flint-and-steel method is the principle used in most cigarette lighters today.

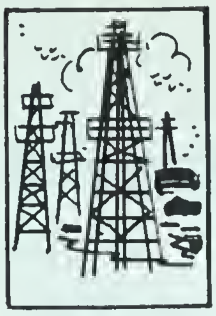
In 1827, an English druggist discovered that a mixture of sulfur, potassium chlorate, and antimony sulfide would ignite by friction. He put some on a splint of wood, scratched it on sandpaper, and made the first friction match. Later, experiments were tried with other mixtures. Some lighted too easily, and were therefore dangerous. Our modern safety match was developed by putting the easily ignited phosphorus on the box instead of on the match.

Galileo and other early scientists suggested that heat was produced by the motion of the molecules of a substance. As was so often the case, the people of that time were not convinced. One day in 1792, Count Rumford was boring into a piece of brass under water. He found that the water became so hot it almost boiled. From this he concluded that heat is produced by friction, or by the rubbing of one thing against another.

About 1774, Joseph Priestley wrote an account of his experiment with red oxide of mercury, which led to the discovery of oxygen. The discovery of oxygen is important for many reasons. One of these is the knowledge that oxygen is responsible for burning. Another reason is the tremendous aid the experiment gave to others in learning the nature of chemical elements.

A French scientist, Lavoisier (la-*vwah*-zee-ay), continued experiments with oxygen. In one of these, he pumped most of the air from a container and heated some tin in the partial vacuum. He found that there was no gain in weight by the tin. Then he heated tin in a container filled with air, which of course contained oxygen, and found that there was a gain in weight by the tin. He thought, therefore, that some part of the air combined with the tin during burning, and caused it to weigh more. Later he proved that it was oxygen which combined with the tin.

Modern homes and industries use a tremendous amount of gas for fuel. Some modern gas storage tanks are shown on page 59.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What gases are in the air? **2.** What gas in the air makes things burn? **3.** Why do fires need a draft? **4.** Why are paper and wood used in starting a coal fire? **5.** Why do lamps and stoves have chimneys? **6.** Why does water put out a fire? **7.** What makes iron rust? **8.** Why are metals painted? **9.** What is a fuel? **10.** What elements in a fuel burn? **11.** What are the products of combustion of the common fuels? **12.** What is the nature of heat? **13.** How was coal formed? **14.** How can we put out fires?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

atmosphere	the whole mass of air surrounding the earth.
chemical change . . .	a change which results in the formation of new substances with completely different properties.
combustion	a chemical change, such as burning, in which heat and light are produced.
compound	two or more elements, chemically combined.
element	a form of matter which cannot be divided into any simpler form of matter by ordinary chemical means.
kindling temperature	the lowest temperature at which a fuel will take fire and continue to burn.
mixture	a substance containing two or more materials that have intermingled without a chemical change. Each material retains its own original properties.
oxidation	(ock-sih-*day*-shun), the combining of a substance with oxygen.
oxide	(*ock*-side), a compound containing oxygen and one other element.
physical change	a change in the form of a substance without any change in its chemical composition.

A What gases are in the air?

The air contains several different gases. Air does not have the same composition at all times. Then, what causes the change? You have probably noted that air in a room that is poorly ventilated does not seem as refreshing as outdoor air. Does the breathing of animals and people affect the composition of air? Do fires affect its composition? We can show the presence of some of the gases in air.

DEMONSTRATION

Put a small candle (Fig. 3-1) upright on the bottom of a dish. Pour in some water. Light the candle and put a glass jar over it. Let stand until the jar is cool. Result? Conclusion? Now slip a piece of cardboard over the mouth of the jar. Raise the jar out of the water and turn it mouth up while still covered. Measure the amount of water in the jar in inches and compute the fraction of the jar filled with

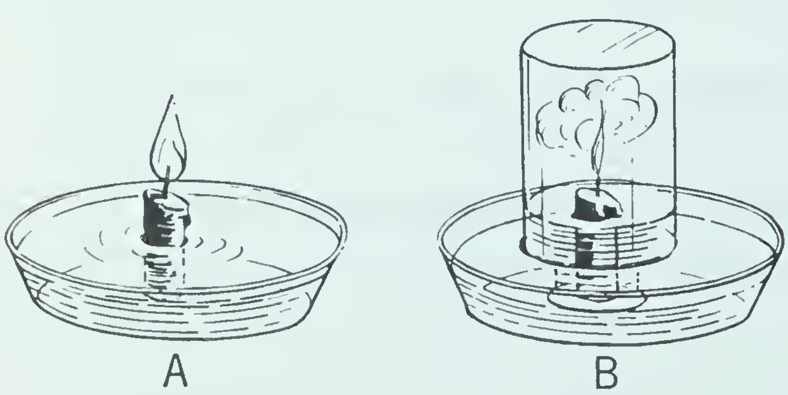


Fig. 3-1. What reasons can you give for the rise in water in the glass beaker at the right?

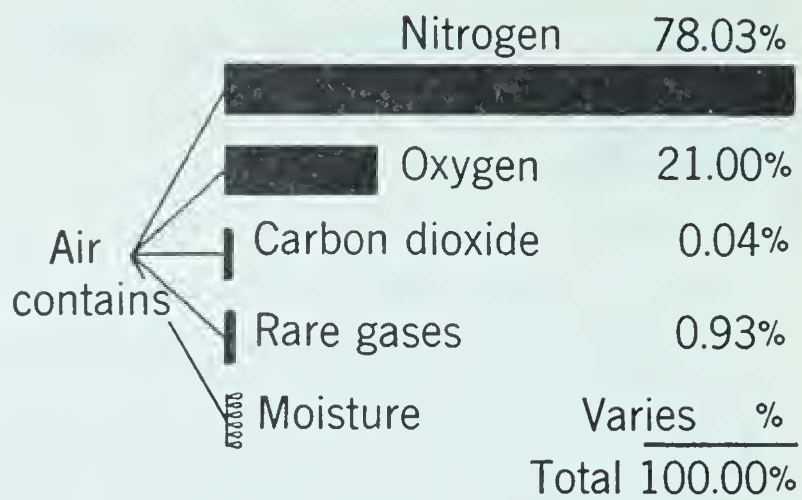


Fig. 3-2. This table shows the various gases of which air is composed, and their amounts.

water. What per cent of the jar is filled with water?

Light a candle, remove the cardboard cover, and put the candle in the jar. Result? Conclusions?

Evidently the burning candle has used up some of the air in the jar, since water rises in the jar. That part of the air which is removed is ***oxygen*** (*ock*-sih-jen). The amount of oxygen in the jar is roughly measured by finding how much of the jar is filled with water. Most of the gas still remaining in the jar did not support burning. This is ***nitrogen*** (*nite*-roh-jen). Since about one-fifth of the air was used by burning, we say that about one-fifth of the air is oxygen. About four-fifths is nitrogen. Chemists have measured the composition of the air by volume. Look at Fig. 3-2 to see of what gases air is composed.

PUPIL ACTIVITY

Moisten the inside of a test tube with water and put a small amount of iron filings in it. Shake well until a layer of filings clings to the inside of the test tube (see Fig. 3-3). Invert the tube in a glass containing a small amount of water. Note

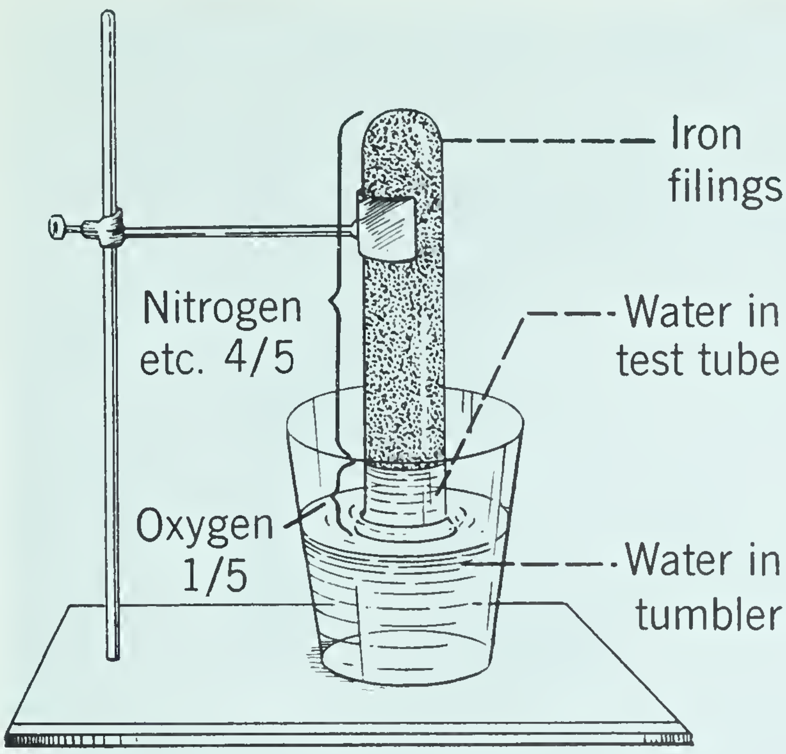


Fig. 3-3. When oxygen unites with iron, a new product, iron oxide, is formed. This is commonly called rust.

the amount of air in the tube. Put a second tube in the glass under the same conditions as the first but without any iron filings in it. Why?

Let both tubes stand overnight. What portion of the air was removed from the first tube? From the second tube? What per cent of the air was removed from the first tube? What must have removed it? What gas has been removed? Why?

About one-fifth of the air has been used, and replaced by water. The water has been pushed up to fill the space originally occupied by the oxygen. The oxygen has united chemically with the iron to form an *oxide* (*ock*-side). The oxide formed occupies so little space that it does not noticeably affect the result. It is possible to use phosphorus instead of iron. The oxygen will unite with the phosphorus in the same way to form an oxide. The space first occupied by the oxygen will be filled with water.

Joseph Priestly discovered oxygen. He put some mice in a jar containing oxygen and noticed that they scampered around at a lively rate. Then he tried breathing it himself. He said it gave him a feeling of liveliness, so he called it "perfect air." Later, Lavoisier called it *oxygen* which is the name we use today.

What are the properties of oxygen? This gas is odorless and colorless. It does not burn, although it causes other things to burn. It is the most abundant element we know. Oxygen combines with another element, hydrogen, to form water. By weight, about 89% of water is oxygen. Oxygen also is combined with many other elements in the form of rocks and sand. About half of all rocks and sand is oxygen. The amount of oxygen in the atmosphere is small compared with that found combined with the other elements that make up the earth's crust.

Pure oxygen has many uses. In medicine, it helps people who suffer from certain diseases to breathe more easily. If used in time, it revives people who are almost suffocated from poisonous gases. It will save the lives of many people who have almost drowned.

Oxygen, when combined with gaseous fuels by combustion, produces very high temperatures. At these temperatures, metals may be welded.

The major gases in the air have special properties. The gases in the air are mostly oxygen and nitrogen. From the first part of the demonstration in Fig. 3-1, you saw that the burning of a candle removed oxygen from the air. From the second part of the

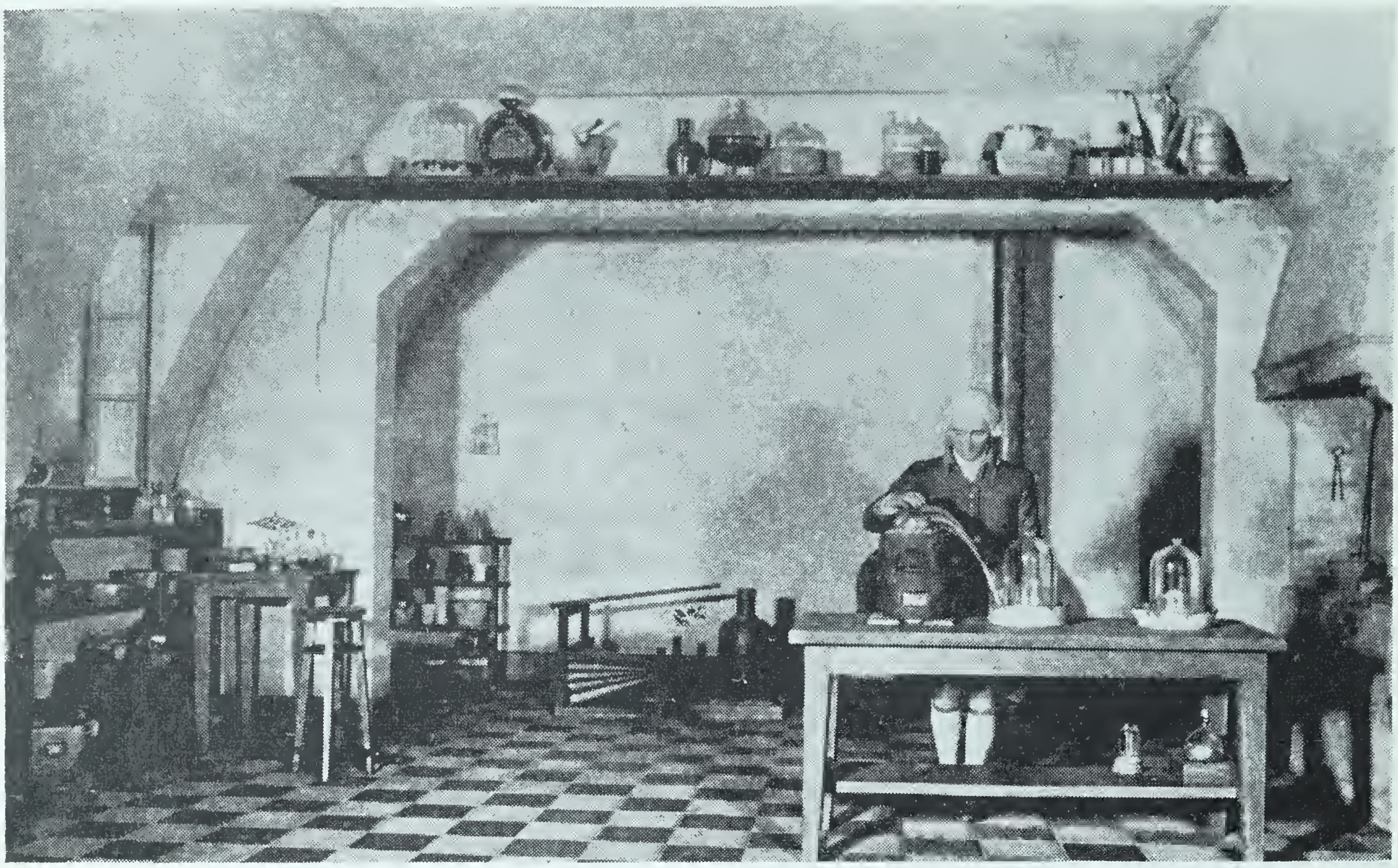


Fig. 3-4. The French scientist, Lavoisier, is said to be the father of modern chemistry. In his laboratory, shown here, he discovered the true nature of burning.

demonstration, you saw that after the oxygen had been used up by the burning of the candle, no burning could take place in the jar. The taper went out because the oxygen was nearly gone. This shows that oxygen is necessary for burning. Without oxygen, substances usually do not burn.

From the Pupil Activity in Fig. 3-3, you learned that oxygen can also be removed from air by allowing it to combine with some other substance. This forms a different substance. Nitrogen does not support burning as oxygen does. Chemists consider oxygen an active gas by comparison with many other gases, since it combines readily with other elements.

Inert gases in air do not combine with other substances. Until 1894, scientists thought that air contained only oxygen, nitrogen, carbon dioxide, and water vapor. At this time, two English scientists startled the scientific world by telling of a strange element in the air, which they called *argon*. Then in quick succession it was announced that other rare gases—*neon* (*nee*-on), *helium*, *xenon* (*zee*-non), and *krypton* (*krip*-ton)—were also found in the air.

So far chemists have been able to make these rare gases unite with only a few other elements. The rare gases were discovered by cooling the air to very low temperatures. Chemists found that after the carbon dioxide, nitrogen, and oxygen had been changed to liquid form there was still some air left. By cooling the remainder of the air to still lower temperatures, the other gases changed to liquids.

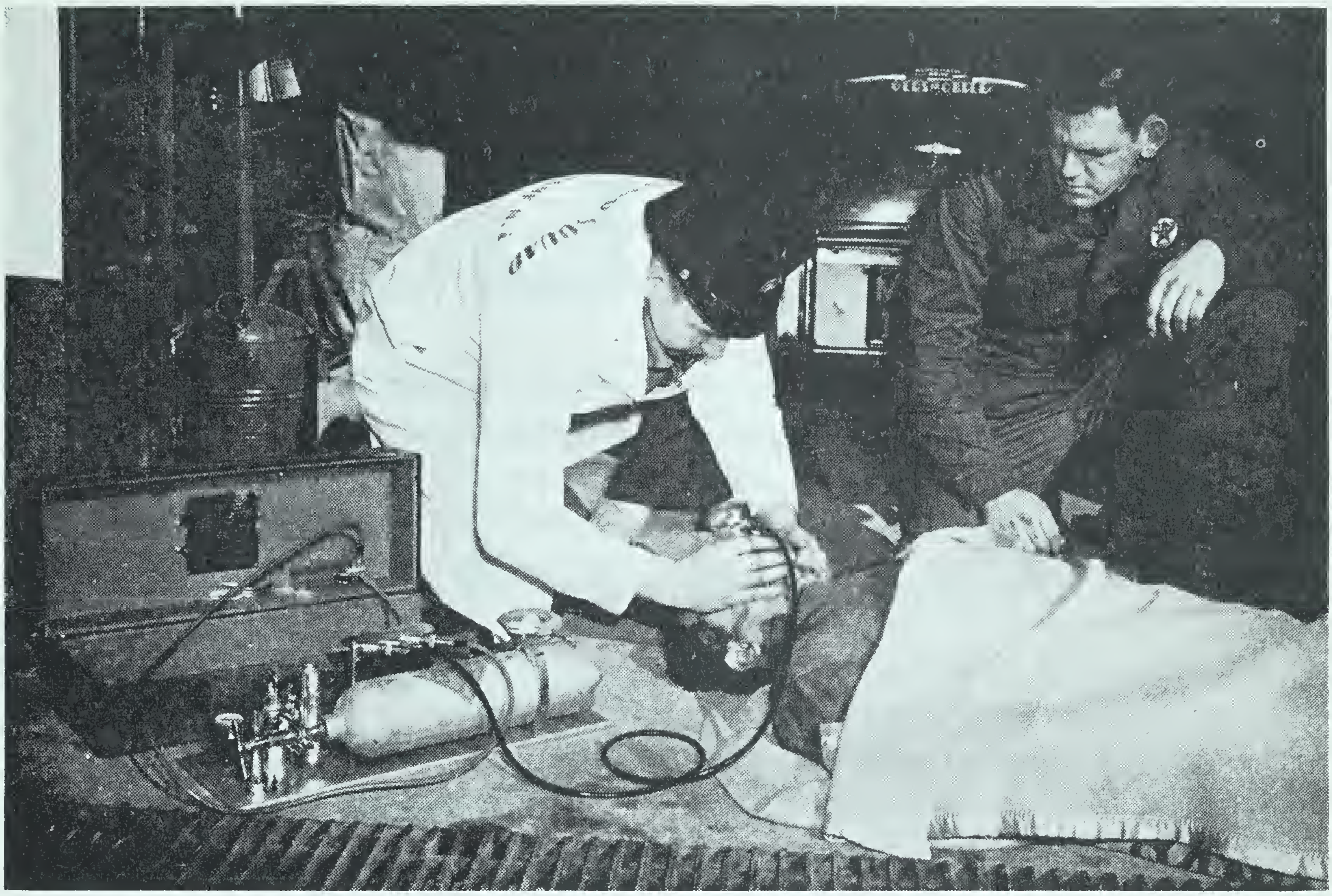


Fig. 3-5. Pure oxygen is used here to revive the victim of carbon monoxide suffocation.

There are other substances in air. We have already noted the varying amount of water vapor in the air in Unit 2. This was evident when we studied the measurement of air pressure by the barometer.

Chemists can also show that air contains carbon dioxide, although it occurs in small amounts (see Fig. 3-2 on page 62).

Air also contains small quantities of dust, smoke particles, tiny living things, and other materials. Actually, these are not parts of air, but are impurities found in it, especially at low altitudes.

The chemist divides all forms of matter into elements, compounds, and mixtures. Oxygen, nitrogen, hydrogen, and iron are examples of *elements.* We call them *elements* because chemists have never been able to divide them into simpler substances by chemical means. They have never divided oxygen into any other substance. Iron is an element because it has never been divided into anything but iron. We will learn more about elements in Unit 15.

Chemists also divide matter into compounds and mixtures. Let us have a look at these important substances for a minute.

Compounds are an important class of substances. A *compound* is formed when two or more elements combine chemically so that the resulting substance differs from the elements out of which it was made.

Water is a compound because it consists of hydrogen and oxygen chemically united. But water does not have

the properties of either hydrogen or oxygen. Other examples of compounds are carbon dioxide and iron oxide.

The elements in a compound are so well bound together by chemical attraction that it requires either intense heat, chemical action, or electricity to separate them. There are thousands of different compounds. The study of their formation is part of the science known as *chemistry.* We shall learn more about this subject in Unit 15.

Inert gases like neon, argon, and helium are called "lazy" because they do not ordinarily combine with other elements to form compounds.

Air is a mixture of elements and compounds. As previously stated, air is composed of several different gases. The oxygen, nitrogen, and argon in it are *elements.* The water vapor and carbon dioxide in it are *compounds.* Because all these gases in air are mixed together (in proportions that vary with time and place) we say that air is a *mixture.* A *mixture* is a substance in which the various elements and compounds have mingled in such a way that each one retains its own properties. Each gas in the air always retains its own individual properties, even though it is part of the mixture. In Unit 15 we shall learn more about mixtures.

REVIEW QUESTIONS

1. What gases are found in air? **2.** What is the approximate per cent of each? **3.** What is an element? A compound? A mixture? **4.** Why is air said to be a mixture? **5.** Name three elements; three compounds; three mixtures. **6.** Who discovered oxygen? Who named this gas?

B What conditions are necessary for combustion?

The oxygen in air is necessary for burning. In a previous demonstration, you saw that a candle could not burn unless there was oxygen present. Fuels cannot burn unless oxygen is present. The burning of any material, with the production of heat and light, is called *combustion.*

DEMONSTRATION

Put a small amount of fresh sodium peroxide into a test tube. With a medicine dropper add *just a few drops* of water. Test from time to time by thrusting a glowing splint of wood into the test tube. What happens? This is the test for oxygen. Why is oxygen sometimes called "fire gas"? What is its color and odor? What would happen if air were pure oxygen?

Certain conditions are necessary in order to make a fire successfully.

PUPIL ACTIVITY

Light a candle. Put an inverted glass over it. Results? Conclusion? Verify by repeating the experiment and this time tilt the jar so that air will enter. Result? Conclusion? Put a candle in an empty upright jar. Put splints of wood near the wick. Now light the candle. Move the splints gradually toward and into the flame. Results? Will air alone start combustion? What three conditions are needed to start combustion?

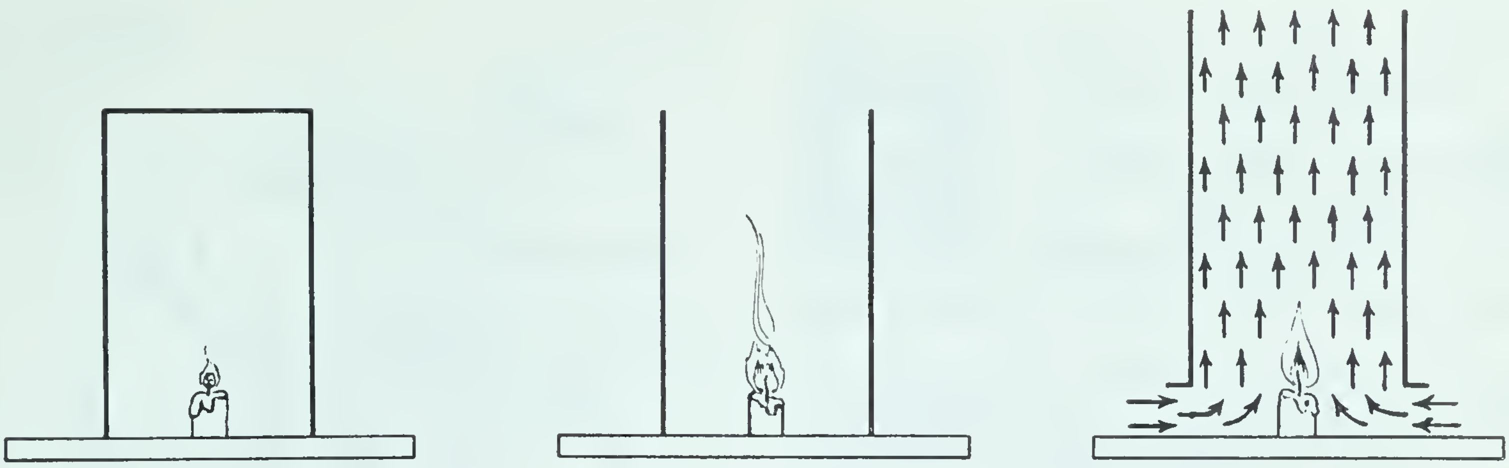


Fig. 3-6. From these drawings tell what three conditions are necessary to start a fire and to keep it burning?

To start a fire: (1) you must have air or oxygen; (2) you must have a fuel; and (3) you must heat up the fuel to its kindling temperature. How are these illustrated in the Pupil Activity above?

A fuel is necessary if we are to have combustion. In order to have a fire, we must have something to burn. Our chief fuels are: (1) *solid materials* like wood, coal, and coke; (2) *liquids* like kerosene, gasoline, and fuel oil; and (3) *gases* like natural gas. We call them fuels because they burn easily and because a small quantity produces a large amount of heat. Can you think of other fuels in different parts of the world?

Everything that burns cannot be called a fuel. Some substances, like iron, do not burn except in pure oxygen at high temperatures. Therefore, iron is not used as a fuel. It, and other substances like it, are ***incombustible.*** This means that they will not burn at ordinary temperatures. We say fuels are ***combustible*** if they will burn at ordinary temperatures.

A substance must be heated to its kindling temperature in air before it will burn. You could not very well start a fire by trying to light wood logs.

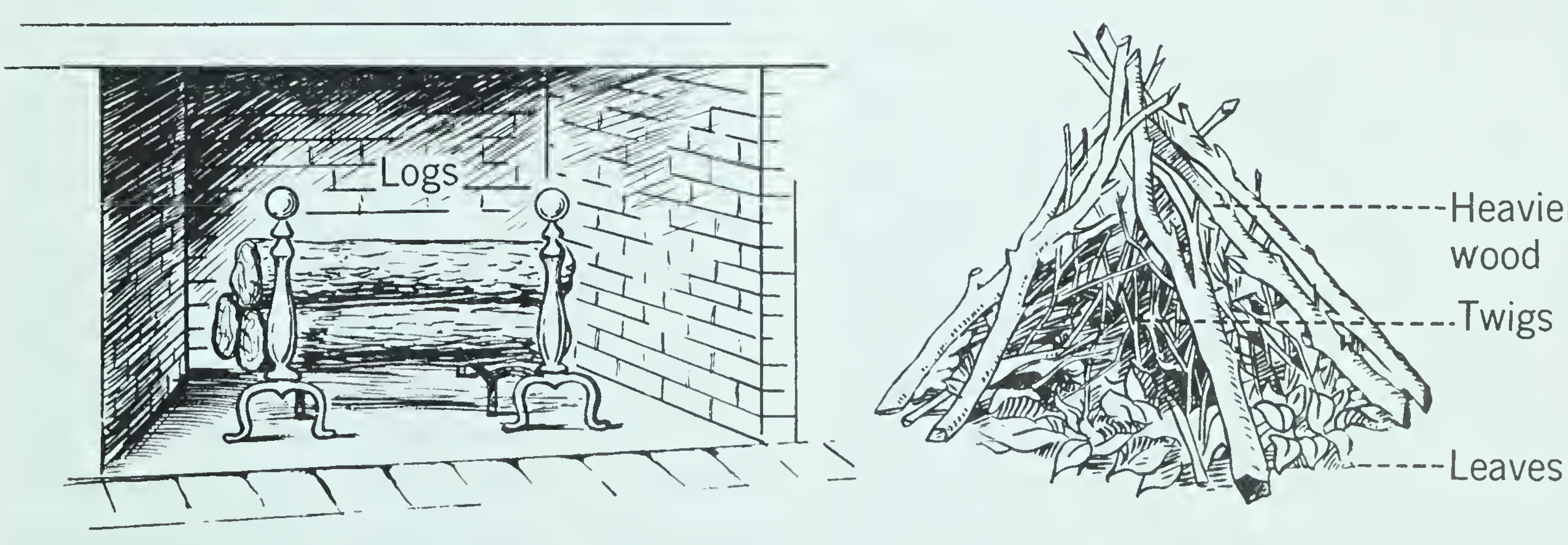


Fig. 3-7. To start a fire, you must use a material with a low kindling temperature like leaves (or paper).

However, every Boy Scout knows that the proper way to start a fire is to use leaves first, then small twigs, and finally heavier wood. When he heats leaves with a lighted match, the leaves will begin to burn. The heat from the burning leaves will heat the twigs to their *kindling temperature*. The ***kindling temperature*** is the lowest temperature at which a substance will burn. When the twigs burn, they will heat the heavier wood to its kindling temperature. And when the heavier wood starts to burn, the logs can be thrown on the fire.

Fortunately, there are few substances which will unite with the oxygen of the air fast enough to catch fire and burn at ordinary temperatures. Some substances, such as phosphorus, have a low kindling temperature. Others such as hard coal, have a high kindling temperature.

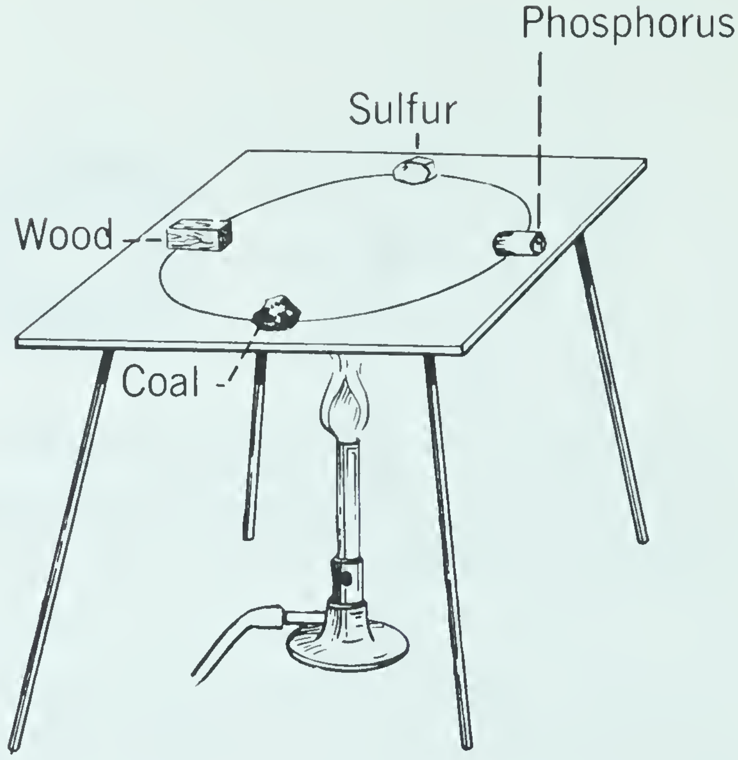


Fig. 3-8. Of the various substances shown here, which has the highest kindling temperature? Which has the lowest?

DEMONSTRATION

(A) Put a small piece of phosphorus, some sulfur, a small block of wood, and a small piece of coal on a metal plate. Be sure the four materials are at equal distances from the point on the plate above the flame, as shown in Fig. 3-8. Why? Heat the plate gently. Which material ignites first? Which next? Which last, if at all? Which burns at the lowest temperature? Which material has the highest kindling temperature? Why are phosphorus, sulfur, and similar substances used in making matches? Why are wood shavings used in starting a fire? Why is it best to put small pieces of coal on a fire before adding large pieces?

(B) Light a match. What part ignites first? Note how the flame travels from one part to another. What chemicals are on the match head? Why is the match head rubbed on a rough surface? What are safety matches? Why must you rub them on a box?

In starting a fire, you bring a lighted match to its kindling temperature. You then put this next to the material with which you wish to start your fire. The material reaches its kindling temperature and starts to burn. The burning material furnishes enough heat to raise the logs or coal to their kindling temperature. A blazing fire results. Now, do you see why we call thin slats of wood by the common name of *kindling wood?*

A flame is a burning gas. A fire is the burning of some fuel. This burning is often accompanied by a flame. Charcoal and various other substances burn without a flame. When you see a flame, you know that a gas is being burned. This gas is produced when the fuel itself or part of the fuel is changed to

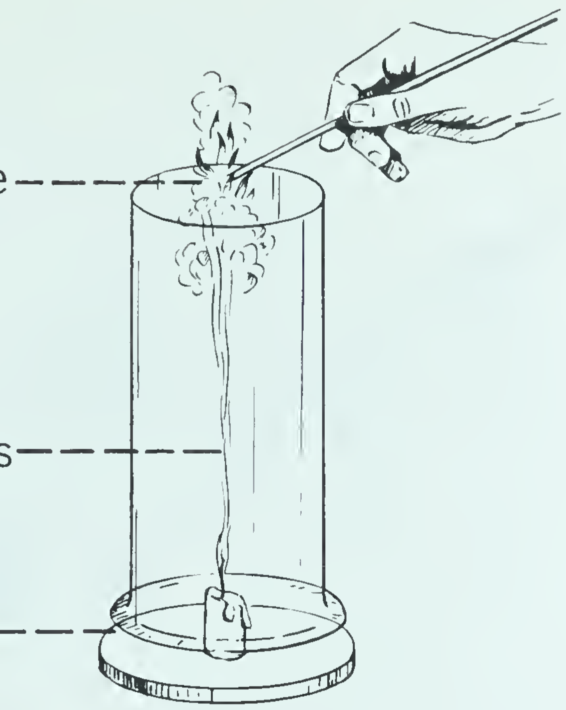


Fig. 3-9. The solid paraffin in the candle vaporizes into a gas which then burns with a flame.

gas. Before the liquids, gasoline or kerosene, are burned, they must be changed to a gas. Coal and wood contain materials that will change to gases when heated. It is these gases that cause coal, wood, paper, and other substances to burn with a flame.

REVIEW QUESTIONS

1. What three conditions must you have to start a fire? **2.** What is the difference between combustible and incombustible materials? **3.** What is kindling temperature? **4.** What is a flame? **5.** What are the three different classes of fuels? **6.** What are the advantages of liquid and gaseous fuels over solid fuels? What are the disadvantages? **7.** What three substances have low kindling temperatures? **8.** The kindling temperature of yellow phosphorus is 95° F. Why is it very dangerous to handle phosphorus with your fingers? (*Hint:* What is the average normal temperature of the human body?)

C What is oxidation and how is it related to combustion?

Oxidation is the uniting of some substance with oxygen. In Part A of this unit you saw how oxygen was removed from a jar or a test tube by burning a candle. You also saw how iron filings combined with oxygen.

Combustion is really a form of oxidation. We know that the burning of the candle is combustion. Since the material in the candle combines with the oxygen in the air, it is easy to see that combustion is a form of oxidation. Combustion is called ***rapid oxidation,*** while the formation of iron oxide or rust on the iron filings is an example of ***slow oxidation.***

DEMONSTRATION

Put a small amount of fresh sodium peroxide into a dry widemouthed bottle. Fit the bottle with a two-hole stopper. Into one hole insert a medicine dropper full of water, being careful not to let any water get into the sodium peroxide. Set up the bottle with a delivery tube as shown in Fig. 3-10. Squeeze the bulb of the dropper to add water a few drops at a time. Collect the gas over water, being sure that the collecting bottle is full of water before inverting it. Heat a small piece of steel wool until it is red-hot and *quickly* plunge it into the bottle of oxygen that you have already collected. Result? Will steel burn in air? In pure oxygen? Notice the small black beads that fell from the burning steel wool. What is their composition?

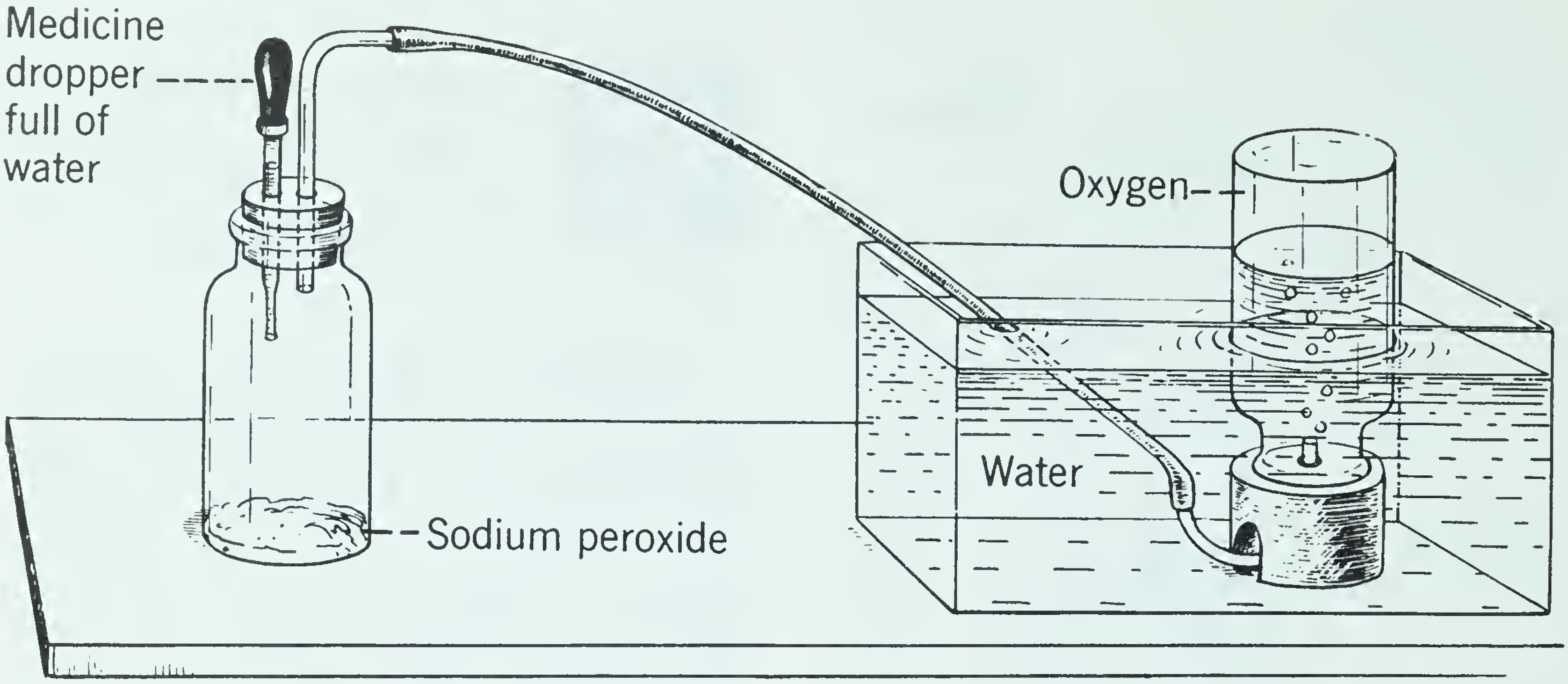


Fig. 3-10. In this demonstration, note that the oxygen produced from the sodium peroxide is collected in the jar by the displacement of water.

PUPIL ACTIVITY

You can prepare oxygen from some simple materials that you may have at home. Break open an old flashlight dry cell and take out a little of the black powder with which it is packed. This contains the compound manganese dioxide. Next, pour about an inch of hydrogen peroxide into a test tube. Now put a pinch of the black powder into the hydrogen peroxide. The gas that bubbles out is oxygen. Test with a glowing splint to prove it.

Oxides are formed during the oxidation of elements. When the iron wire burned, oxygen united with the iron to form a compound called *iron oxide.* This oxide was formed rapidly, and the process was accompanied by much light and heat. It is an example of rapid oxidation.

The burning of fuels with the production of light and heat, as well as the production of oxides, also illustrates rapid oxidation. The explosion of gunpowder is another example of very rapid oxidation.

When the iron filings rusted, oxygen combined slowly with the iron to form an oxide of iron, or *iron rust.* This is an example of *slow oxidation.*

Heat and light are usually the products of oxidation. We know both heat and light are produced by the burning of a candle. When the steel wool burned in pure oxygen, we saw the light produced by the oxidation process. The steel wool would have been very hot, if you had touched it when it was withdrawn from the bottle. Heat is also produced during slow oxidation, as in the rusting of iron. Here the heat is produced so slowly that you do not notice it at all. Rusting of iron produces as much heat as burning it, but you never realize this because the heat escapes as fast as it is produced.

Slow oxidation is prevented by keeping air away from materials. We know that air containing oxygen must

be present if we are to have combustion or rapid oxidation. Then if we want to prevent oxidation, we can do so by keeping air away.

Rusting, or *slow oxidation,* is a serious problem everywhere. It is estimated that from one-fourth to one-third of the manufactured iron and steel products rust each year. Once iron has started to rust, the rust formed helps the remainder of the iron to rust. Metals like lead, tin, aluminum, and copper form protective coatings when they oxidize. That prevents more of the metal from oxidizing. But iron rust acts in just the opposite way. That is why it is so hard to keep iron from rusting. However, since iron and steel are so useful it is usually easier to paint them or to plate them with some other metal than it is to substitute some other material for them.

PUPIL ACTIVITY

Put a few bright nails in tap water, and a few in boiled water. Let both stand a few days. Result? Is there oxygen dissolved in the water? Did boiling the water drive out the air? Does ordinary water help rusting? Wet a clean nail and keep it for a few days, comparing it with a dry one.

Cover some bright nails with grease, paint, stove polish, or linseed oil. Put a bright nail with these nails as a check. What is a check or control? Also put with these an enameled cup, a tin cup, a piece of zinc, a piece of tin, and a nickel-plated object. What is the practical value of stove polish, enamel, galvanizing, nickel or silver plating, and painting?

Carpenters grease their tools when putting them away. Iron bridges and battleships are painted to keep them from rusting. Metals which oxidize easily are plated with other metals

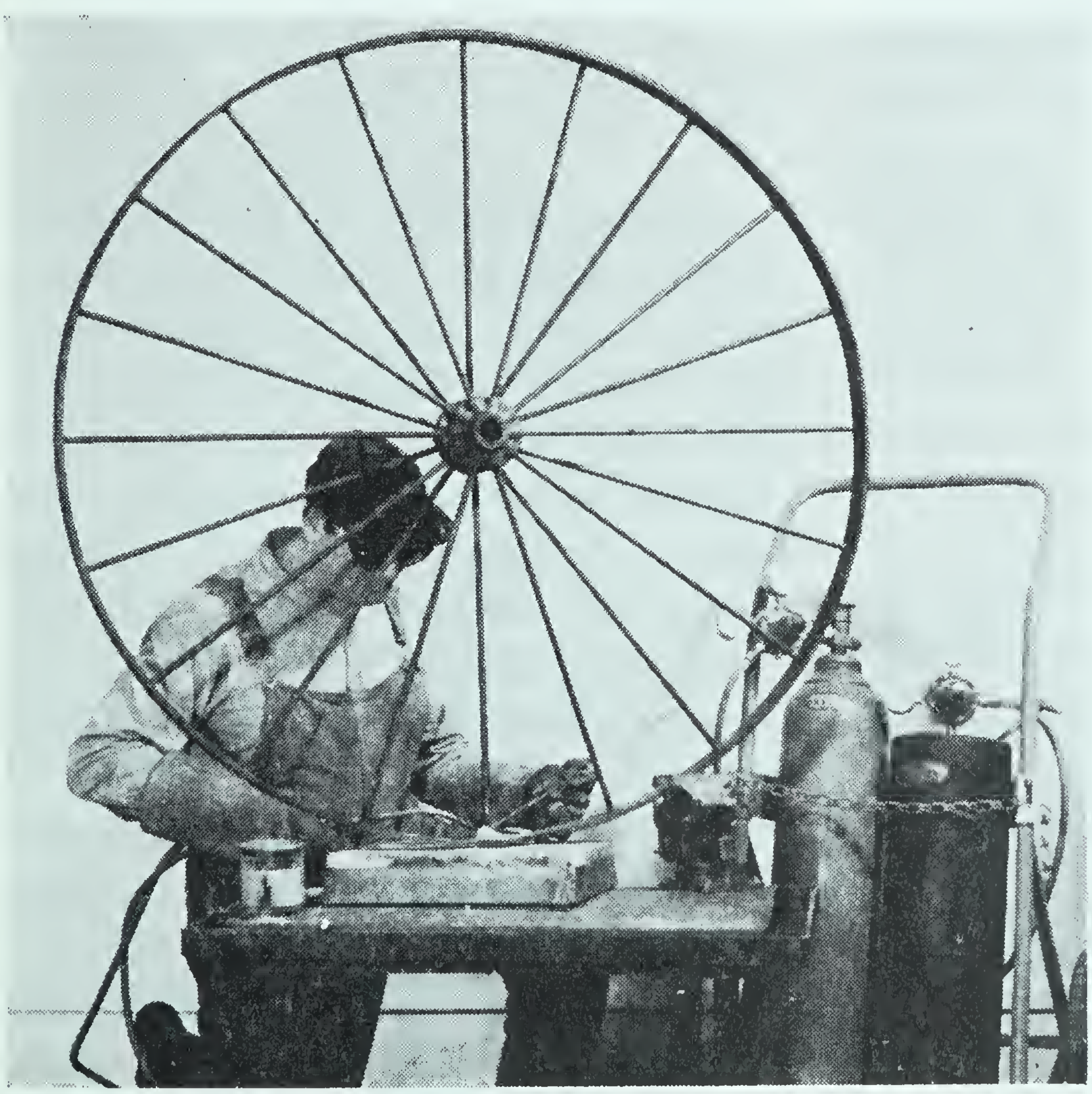


Fig. 3-11. Compressed oxygen and acetylene combine to produce a temperature of from 3400° to 3700° Centigrade. The combination of gases is used to weld strong metals.

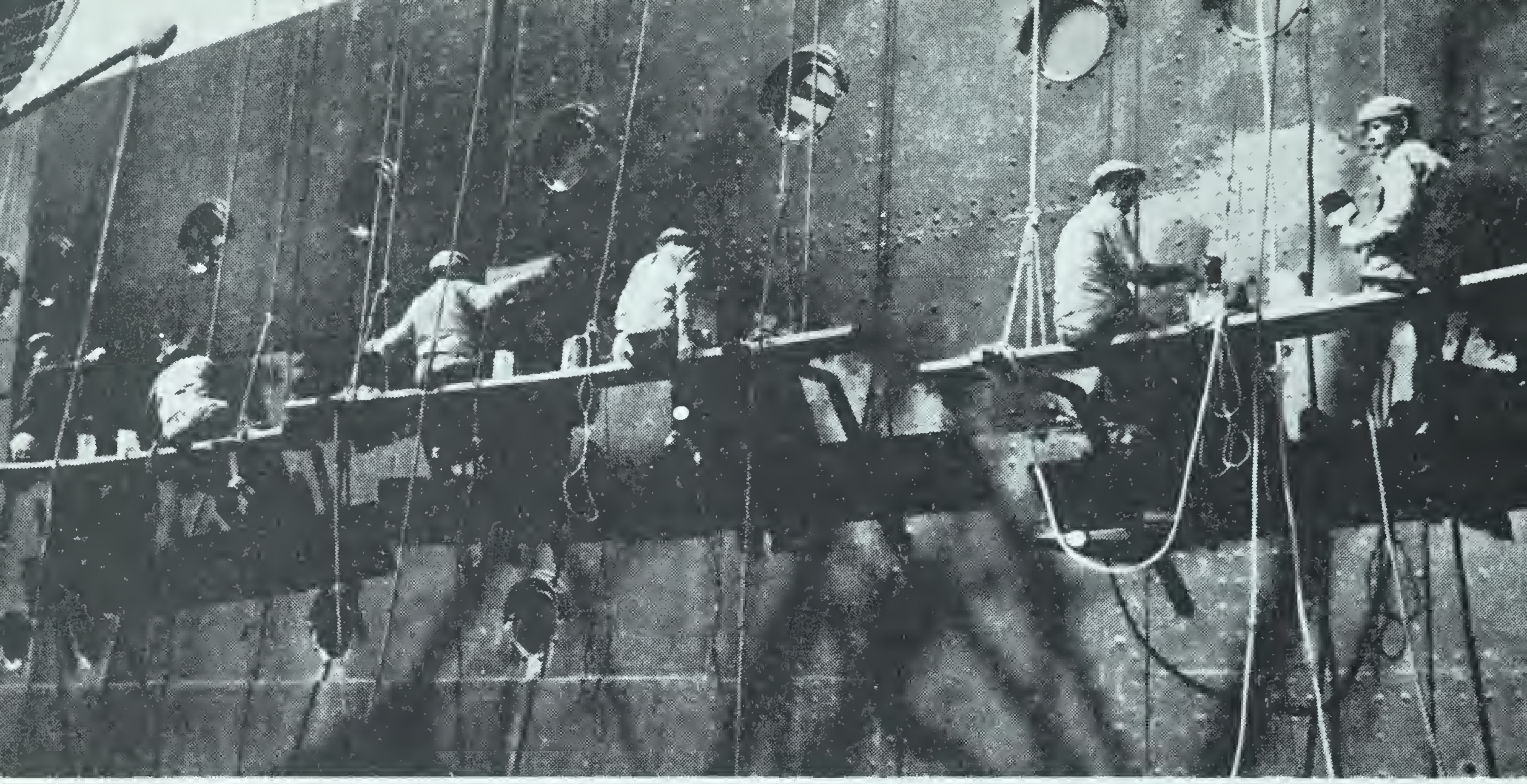


Fig. 3-12. By giving this ship a thorough coating of paint, the iron in its hull is protected from the oxygen in the air. As long as the paint stays on, no rust can form.

which do not oxidize easily. When iron is galvanized, it is coated with zinc. Tin cans are made of sheet iron coated with tin. Because chromium does not oxidize easily, we use it to cover many different substances to keep them from oxidizing. All these methods protect metals that oxidize easily by covering them with a thin layer of some material that is not normally affected by oxygen. In Fig. 3-12, workmen are painting a ship to protect the metal from oxidation.

REVIEW QUESTIONS

1. What is oxidation? **2.** Distinguish between slow and rapid oxidation. **3.** What is an oxide? **4.** What is rusting? **5.** How can you prepare and collect oxygen? **6.** What forms of energy are products of oxidation? **7.** What various methods can you use to prevent articles from rusting? **8.** How are oxides formed? **9.** How may the rate of combustion of a fuel be increased? Be decreased?

D What are the products of the combustion of fuels?

Carbon burned in air produces carbon dioxide. When some fuels burn, a great deal of smoke is given off. With other fuels you see little or no smoke. What makes the difference? After some fuels have burned there are ashes left; yet when oil or alcohol burns, no ashes remain. What are ashes? In addition to heat and light, what products are always formed when fuels unite with oxygen?

Coal and wood are composed largely of carbon and hydrogen. What happens when these elements burn?

The following Pupil Activity will aid you in finding the answers to these.

PUPIL ACTIVITY

(A) Put a lighted candle or a burning splint in a large bottle or jar and then cover it. When it has stopped burning, remove it quickly. Pour some limewater into the bottle and shake. What happens to the color of the limewater? Relight the candle or splint.

(B) Fill a beaker with cold water as shown in Fig. 3-13. Put the candle under the beaker so that the tip of the flame touches the bottom of the beaker. What collects on the bottom of the beaker?

(C) Light a Bunsen burner. Turn the collar on the barrel so that a yellow flame is seen. Does this flame get much air through the holes at the bottom of the barrel? Turn down the stopcock until the flame is about an inch high. Put the burner under a clean beaker of cold water. Result? Now turn the collar on the barrel to admit more air through the holes at the base.

Again put a clean beaker of cold water over the flame. What happens?

Is there any difference in the appearance of the two beakers?

Explain any differences.

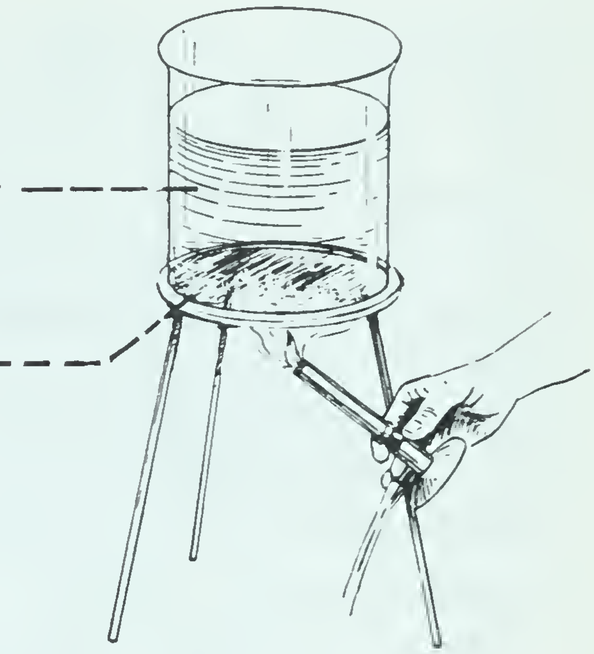


Fig. 3-13. Soot is merely unburned carbon.

When carbon unites with oxygen, carbon dioxide is formed. The limewater shaken in the bottle turned white, indicating that carbon dioxide was present after the candle or splint burned. Thus we know that carbon dioxide is a product of combustion.

Pure carbon, in the form of *soot,* collects on the bottom of the beaker when the flame of a candle or splint is held against it. This carbon does not form if there is enough oxygen mixed with the fuel before it is burned. But if the fuel does not get enough oxygen, soot or carbon is given off and escapes as wasted fuel without being burned. Similarly, when air is not mixed with the gas before being burned in the Bunsen burner, some soot is given off. When the gas is mixed with air, there is little, if any, soot.

If fuels are to be burned efficiently, we must mix air with the fuels before they are burned. Smoke from a fire is evidence that the fuel and air are not being mixed in the best proportions. A good mixture of fuel and air gives a hotter flame and more complete combustion than a poor mixture.

Carbon monoxide gas can be formed in combustion. If a fuel burns without enough oxygen, *carbon monoxide* gas may be one of the products of combustion. This deadly poisonous gas is formed by the burning of gasoline in automobile engines. It also forms in stoves and furnaces, especially if you throw a fresh supply of fuel on a hot fire and leave the drafts closed.

Carbon monoxide is a colorless and odorless gas and therefore is not easily detected. It is very dangerous if it is

breathed even for a few minutes. It burns with a light blue flame and produces carbon dioxide. If there is no oxygen to unite with the carbon monoxide, the latter escapes without being burned. It is often impossible to mix a fuel and oxygen in the exact proportions for complete combustion. Therefore, small quantities of the poisonous carbon monoxide are usually set free whenever a fuel is burned.

Water is formed when hydrogen burns in air. Most of our common fuels contain hydrogen in combination with carbon, or other elements. In its pure form it is a gas which burns with a very hot light blue flame. What becomes of the gas after it has burned?

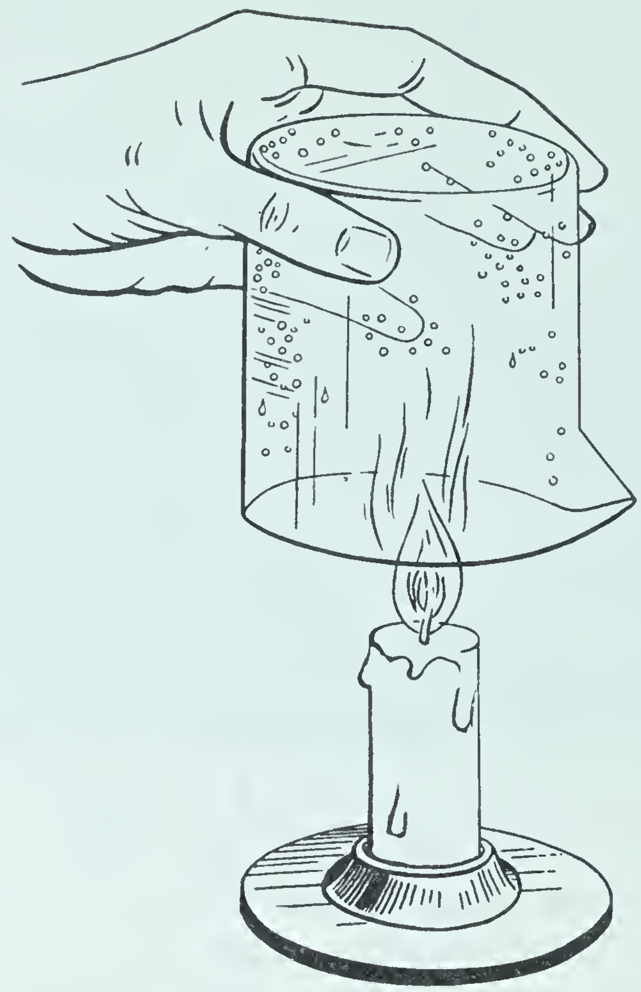


Fig. 3-14. If a fuel contains hydrogen, as does this candle, water is one of the products of combustion.

DEMONSTRATION

Light a candle. Lower a cool, clean, dry beaker, open end down, over the flame as shown in Fig. 3-14. Do you observe anything collecting on the inside of the beaker? What is it? Where did it come from? What did the hydrogen unite with when it burned?

When hydrogen burns, water is formed. Water is likewise produced in the burning of ordinary fuels and is given off in the form of water vapor. When this vapor is cooled, or strikes a cool object, it changes to the liquid form. Water, then, is a product of combustion of the fuels which contain hydrogen.

The products of combustion are formed by chemical changes. In the burning of the candle, oxygen from the air combined with the hydrogen in the candle to form *water.*

You may think it strange that one element can change so completely by combining with another element to form a different product. This is a *chemical change:* one in which other substances with different properties are formed. The identity of the original substance or substances is lost. The burning of fuels is a chemical change because their original properties are

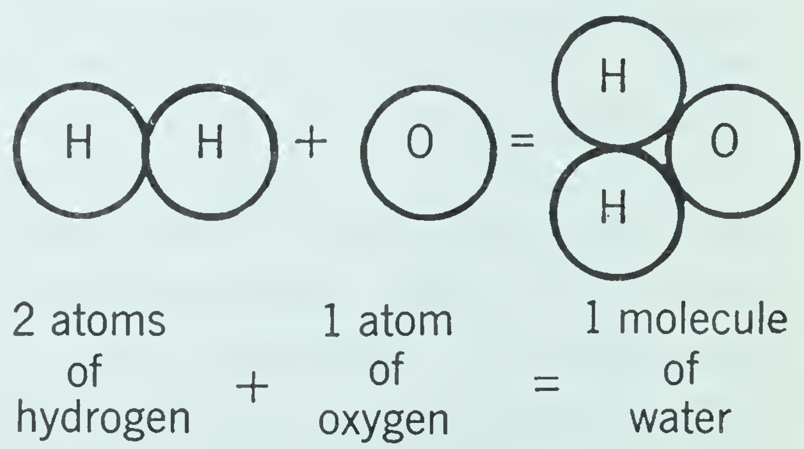


Fig. 3-15. A molecule of water consists of two atoms of hydrogen and one atom of oxygen, chemically joined.

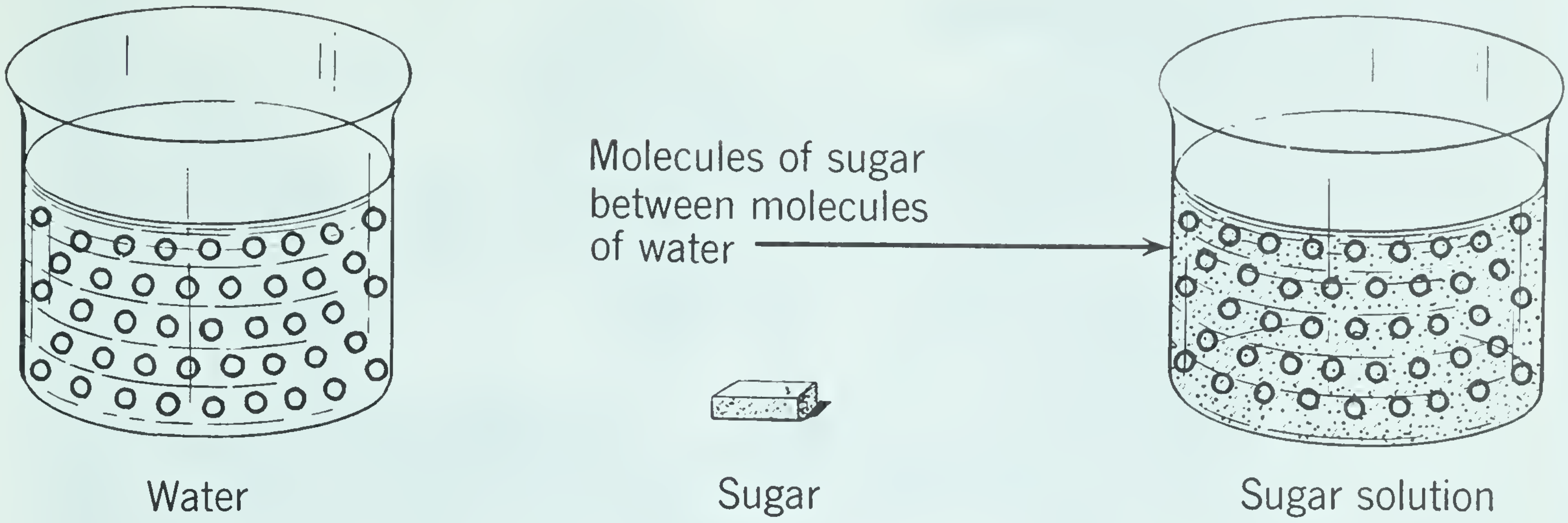


Fig. 3-16. When sugar dissolves in water, there is no change in its chemical characteristics, only in its form and appearance. This is a physical change.

lost in the process. New products are formed, and heat and light are set free.

What is a physical change? What happens when you dissolve sugar in water? The sugar separates into invisible molecules of sugar. If the water evaporates, the unchanged molecules remain in the form of sugar crystals. This is a *physical change,* in which there is a change in the form or appearance of a substance without any change in its characteristic properties.

The freezing of water is another example of a physical change. Ice is really water in solid form. The *melting* of paraffin is still another example.

We know that heat and light are products of combustion. The energy stored in the fuel is chemical energy, a form of potential energy. In the process of combustion, a chemical change occurs with the release of various products of combustion. With this change comes a release of light and heat. The chemical energy in the substance has been transformed into heat and light energy.

REVIEW QUESTIONS

1. What two combustible elements do most fuels contain? **2.** What are the three most common products of combustion? **3.** Under what conditions is soot or carbon given off in burning? **4.** Why is carbon monoxide so dangerous? **5.** Distinguish between a physical and a chemical change. Give an example of each.

E How have our common fuels been formed?

Fuels exist in solid, liquid, or gaseous form. Our chief fuels are wood, charcoal, coke, coal, natural gas, fuel oil, kerosene, gasoline, and alcohol. Can you tell which are solids, which are liquids, and which is a gas? Nature provides some of these fuels for us in the form in which they are used. We get others by treating one of the natural fuels to make it yield a new fuel.

Fig. 3-17. Ancient plants from prehistoric forests, pressure of new growths, sand and mud, as well as the continued heat of the sun—all have contributed over millions of years to help form some of our common fuels.

One of the valuable elements in fuels is carbon. *Carbon* occurs in many forms, such as charcoal, lampblack, coke, hard coal, graphite, and the diamond. It is very hard to dissolve and combines with oxygen to form carbon dioxide.

Coal is actually transformed wood and other substances. Early in the history of the earth, vegetation was very abundant in swampy places and grew to great size. As these plants died, they fell into the water and therefore did not decay easily because they were thus protected from the air. Over long periods of time, these dying plants formed deep layers of rotting vegetation which gradually changed into the substance called ***peat.*** This fuel is found even today in swamps and bogs.

As more of this material accumulated, the weight of the top layers caused the lower layers to become so hardened as to form brown coal, called ***lignite. Bituminous*** (bih-*tyoo*-mih-nuss) ***coal,*** or *soft coal,* was formed in many regions of the world in a somewhat similar way with more pressure from overlying layers. ***Anthracite*** (*an*-thruh-site), or *hard coal,* was formed from soft coal by heat and pressure.

Coal fields occur in several parts of Canada (see Fig. 3-18). Mining is carried on chiefly in Alberta and Nova Scotia. Most of this is bituminous coal. The anthracite we use is imported.

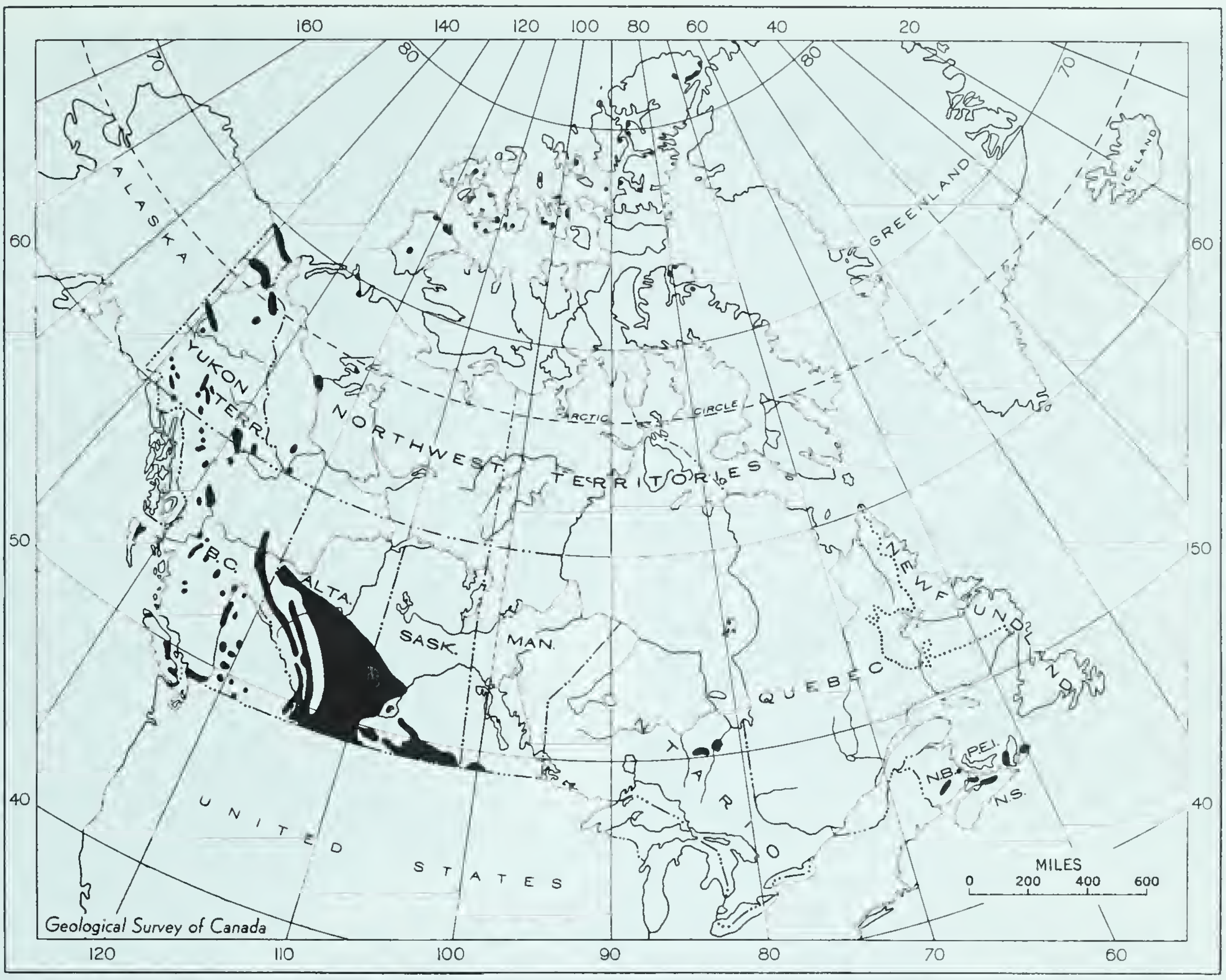


Fig. 3-18. This map shows the regions in Canada where coal is located. Mining operations are most productive in Alberta and Nova Scotia.

Heating soft coal in the absence of air produces coke and coal gas. The product formed by heating coal in the absence of air is another form of carbon called *coke.* It is sometimes used for home-heating, but most of the coke produced in this country goes to blast furnaces that separate iron from its ores. Other substances set free at the same time are fuel gas, ammonia, and coal tar.

When coke is manufactured commercially, the coal is heated in iron chambers called *retorts.* The gas collected from the retorts is called *coal gas.* After it is purified, it is collected in gas tanks and sold in many cities for fuel.

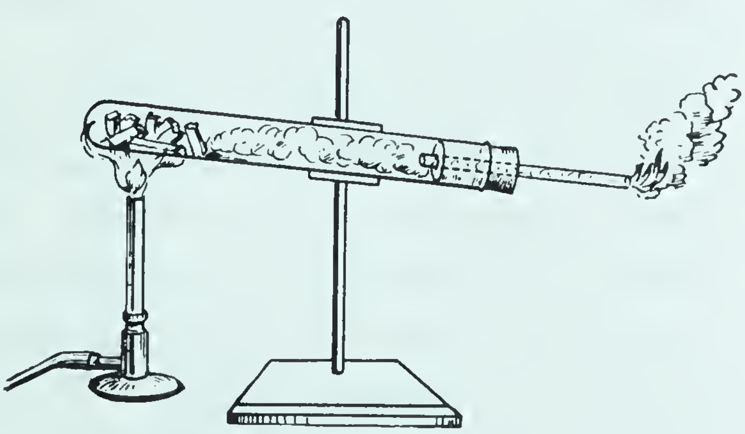


Fig. 3-19. Using this apparatus, you can produce coke and coal gas.

DEMONSTRATION

Fill a hard glass test tube with small pieces of soft coal. Connect the test tube with the apparatus as in Fig. 3-19. Heat the coal thoroughly for several minutes. When gas comes out of the tube, try to light it. Will it burn? Heat until the gas

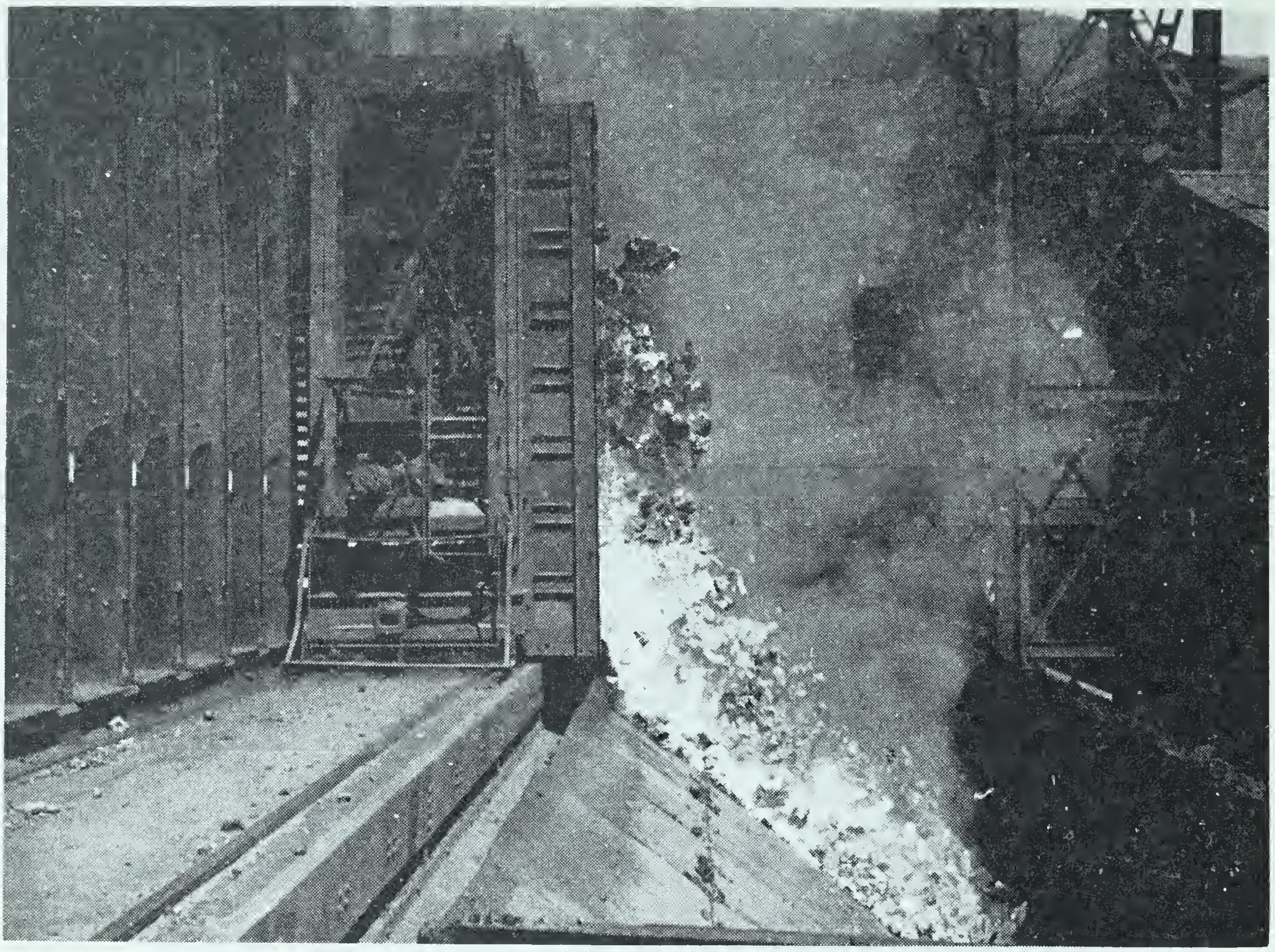


Fig. 3-20. In manufacturing coke commercially, coal is heated in huge ovens. In this photograph the white-hot coke is being pushed from the ovens into a quencher car. Water is then poured over the quencher car to cool the coke.

stops coming out of the tube. Cool the test tube and remove the coal. Examine its properties. What is it? How does it differ from the original coal? Will it burn?

We get water gas by passing steam over red-hot coke or hard coal. The gases formed are carbon monoxide and hydrogen. These gases are colorless and odorless. Because of this, another substance is added to make it easy to detect by the odor. Why is it necessary to be able to smell a gas that contains carbon monoxide?

Until lately, homes and factories in many cities used coal gas and water gas for heating and cooking. Today there is a trend toward the use of natural gas in their places. *Natural gas* is taken from oil wells or collected from "pockets" of gas in the ground and pumped hundreds of miles through huge pipelines to all parts of the country. This fuel is made up of compounds containing carbon and hydrogen. Natural gas gives more heat per cubic foot than either coal gas or water gas.

Petroleum is believed to have been formed by the decay of animal and plant material. This material was probably buried during the changes in the earth's crust. As heat and pressure through the ages continued, petroleum and natural gas were produced.

Petroleum is found in many parts of

Canada. It is an oily liquid from which gasoline, kerosene, and paraffin are separated.

Wood is constantly provided by our forests. It was for ages man's only fuel. There are many parts of the world where coal and gas are not used even today, and where wood is still the chief fuel. However, since abundant supplies of coal and petroleum were discovered, they have provided most of the fuel that made possible our industrial age. They also supply much of the fuel used in our homes.

Heating wood without air produces charcoal and fuel gas. The following demonstration shows how these are formed.

DEMONSTRATION

Fill a hard glass test tube with thin splints of wood. Connect the rubber stopper and delivery tube as shown in Fig. 3-21. Heat the wood for several minutes and put a match to the jet as the wood is being heated. Is a combustible gas being formed? What happens when wood is heated in the absence of air? Disconnect the stopper and the delivery tube. Remove the heated wood from the test tube. Examine it carefully. Try to write with it. Can you break it easily? What is it called? Will it burn?

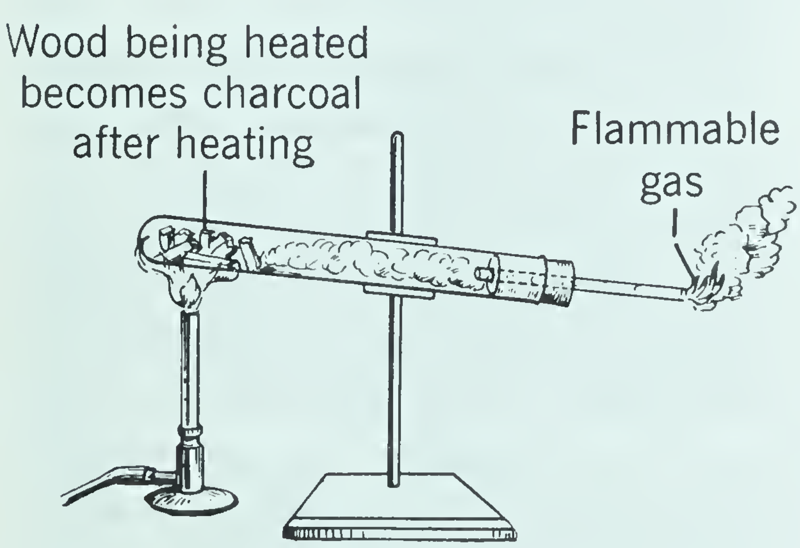


Fig. 3-21. To make charcoal, heat wood in a closed container to keep out oxygen.

The product left in the tube after the wood has been heated is ***charcoal,*** a form of nearly pure carbon. It did not burn in the tube because there was not enough oxygen present. Heating drove the fuel gas, as well as the other products, out of the wood.

REVIEW QUESTIONS

1. What is a fuel? **2.** What are the three classes of fuels? **3.** What explanation is given for the formation of soft coal? Of hard coal? **4.** What is peat? **5.** What is lignite? **6.** Which contains more carbon, soft coal or hard coal? **7.** How are charcoal and coke made? **8.** What is coke and for what is it used?

F How can large losses by fire be prevented?

Most fire losses are due to carelessness and ignorance. Look at the report on page 80 from the Dominion Fire Prevention Association for a recent year. This is for building fires only. The estimated loss from fires of all causes in that year was slightly less than one billion dollars.

Authorities have stated that each year forest fires burn an area equal to a one-mile strip reaching from Vancouver to Winnipeg. Most of these are due to carelessness.

BUILDING FIRE LOSSES IN CANADA

Cause	Percentage
Smokers' carelessness	39.6%
Stoves, furnaces, etc.	9.3%
Electric wiring and appliances	8.9%
Defective chimneys	3.7%
Matches	3.6%
Hot ashes, coals and open fires	3.2%
Petroleum and its products	3.0%
Lightning	2.9%
Lights other than electric	1.9%
Exposure fires	.8%
Sparks on roofs	.7%
Spontaneous ignition	.4%
Incendiarism	.4%
Miscellaneous known causes	9.6%
Unknown causes	12.0%
Total	100.0%

Fires may be put out by keeping air from reaching the fuel. You have already learned that fires require fuel, oxygen, and a certain burning temperature, depending on the substance or fuel used. It is plain, therefore, that there should be three ways to extinguish a fire. They are: (1) remove the fuel; (2) keep oxygen from the fire; and (3) cool the fuel below its kindling temperature. Any of these, or a combination of them, can be used in fire fighting. Fire extinguishers use one or more of them.

DEMONSTRATION

(CAUTION: no one but the instructor should perform this.) Pour enough vinegar or well diluted sulfuric acid into a milk bottle to cover the bottom about ½ inch deep. Add a teaspoonful of baking soda. The gas formed is carbon dioxide. Test it by inserting a lighted match. Result?

Make a small demonstration fire extinguisher, like that shown in A or B in Fig. 3-22. Dissolve a spoonful of baking soda in enough water to half-fill an 8-oz. widemouthed bottle. A milk bottle will serve if you can get a cork to fit it. Fit the bottle with a one-hole stopper. Hang a small vial half-filled with vinegar or dilute sulfuric acid from the neck of the bottle with a small wire. (NOTE: if the sulfuric acid is too concentrated, the reaction will blow the stopper from the bottle with very dangerous consequences!) Insert a short piece of glass tubing into the hole in the cork, and attach a rubber tube.

Ignite some paper in a safe receptacle. Stand back a few feet, hold the stopper firmly in place with your fingers, and turn the bottle over so that the vinegar or acid runs out of the vial. Be careful not to get any of the contents on your clothing, face, or skin. Direct the stream of liquid on the fire in the pail. Result?

When the vinegar or dilute sulfuric acid mixes with the soda solution, carbon dioxide forms. This gas is produced so fast in such quantities that, being confined, it soon exerts enough pressure to force the contents of the extinguisher out of the nozzle. In this type of extinguisher, you are depending mainly on the carbonated water which is forced out of the container with the gas. You should direct the liquid at the base of a fire and on the

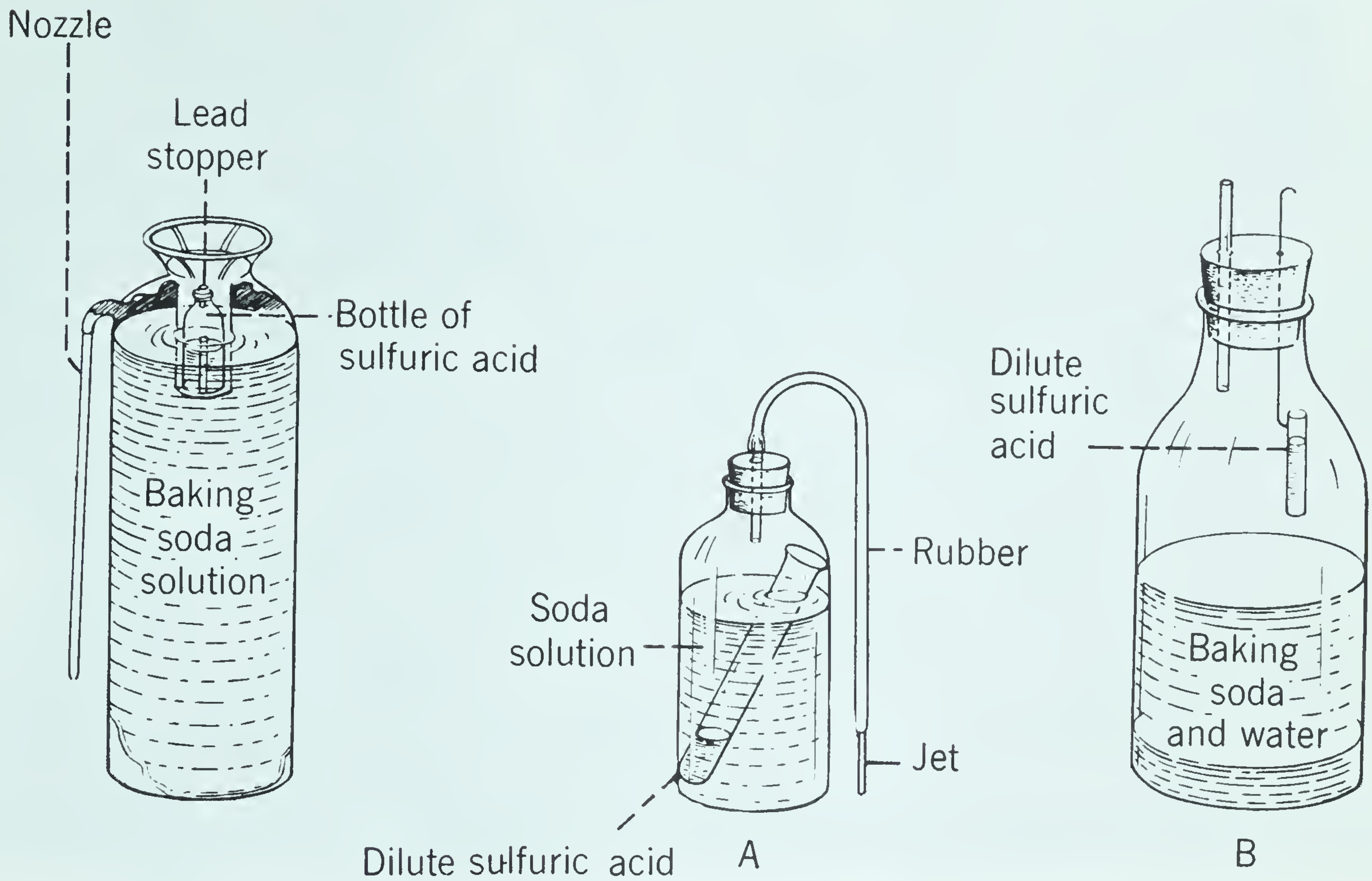


Fig. 3-22. On the left is a cut-away view of a common type of the soda-acid fire extinguisher. In the middle and to the right (A and B) are two ways of making a small soda-acid extinguisher.

burning substance, not above the fuel. Why?

DEMONSTRATION

Pour a very small amount of kerosene into a shallow evaporating dish. Drop in a small piece of paper tissue or paper towel to act as a wick. Light the wick. Pour water on this fire. Result? Fold a piece of cloth into several layers and put it quickly over the dish. Result? Pour some sand or ashes on another fire of the same kind. Result? Spray some carbon tetrachloride on another small fire. Result?

When the flame is out, cover the dish to prevent the fumes from escaping into the room.

Water is not good for putting out fires of petroleum products because they are lighter than water. Therefore, water will spread such fires, rather than extinguish them. When Pyrene extinguishers are not at hand, sand, dirt, or blankets may be used as they keep out the air and are convenient. Never run when your clothing is on fire. Why? It is better to wrap a rug, old coat, or blanket about you quickly, or roll over slowly on the floor and at the same time beat out the fire with your hands.

Fire extinguishers are satisfactory for use with small fires only. It is hard to smother a large fire because the air above it is pushed up, as it is heated, by fresh air from the surrounding area, which supplies more oxygen. Thus a big fire creates its own draft.

Water is used to cool burning fuels below their kindling temperature. When large quantities of water are forced onto the fire, several actions oc-

Fig. 3-23. Fire lanes, like the one being made here, prevent forest fires from spreading by removing the fuel.

Fig. 3-24. On gasoline fires, you should use Pyrene fire extinguishers or smother the fire with sand, dirt, or even blankets.

cur. Cold water comes in contact with the hot fuel and lowers its temperature. Some heat is absorbed by the evaporation of the water. If you add enough water, the temperature of the fuel is lowered below the kindling point, and the fuel stops burning. Water also helps keep air from reaching the burning fuel.

Fires can be kept from spreading if the fuel is removed. One example of the use of this method is in the fighting of forest fires which spread rapidly. This rapid spread is checked by making wide *fire lanes*. These are lanes from which trees, shrubs, and grass have been removed. They stop the fire from spreading and also provide roads for the fire fighting equipment to reach the fire. If caught in time, a forest fire can be put out without much trouble. If not, it can do great damage.

Fig. 3-25. Note the many fire hazards in this home. What measures can you suggest for eliminating them?

Many destructive fires in the home can be prevented. Such fires are started in the home in many ways. The careless use of matches causes the greatest number of fires. Matches should be stored in metal boxes. You should always put burned matches in receptacles made of fireproof materials, instead of throwing them into waste-baskets. Careless smokers also start many fires.

Sometimes combustible gases escaping from a stove or furnace are ignited by a pilot light or a burning match. This may result in a dangerous explosion. Another practice that often leads to explosions is the use of gasoline or kerosene to kindle a fire. It is wiser to use paper or wood for such purposes. Still another foolish action is that of looking for a leak in a gas pipe with a

Fig. 3-26. Why should oily rags be kept only in metal containers instead of being thrown on the garage or cellar floor? What term is used to name fires that are started in this way?

lighted match. Remember never to use an open flame when there are any odors of escaping gas.

People often throw oily paint rags into a corner of the garage or into a container not suited to the purpose. This is a dangerous practice. The slow oxidation of the linseed oil may, in this case, produce enough heat to raise nearby paper or cotton waste to its kindling temperature. When a fire begins in this way, it is called *spontaneous combustion.*

REVIEW QUESTIONS

1. What fire fighting method can be used to prevent air from reaching a fire? **2.** What method is used to lower the kindling temperature of a fuel? **3.** How are forest fires controlled? **4.** What are some unsafe practices which create fire hazards? **5.** What is the difference between ordinary combustion and spontaneous combustion? **6.** Why are fire extinguishers not effective against large fires? **7.** Why is it dangerous to use gasoline or kerosene in kindling a fire? Why is it safer to use paper or wood?

QUESTIONS FOR REVIEW AND DISCUSSION

1. How was the presence of the different gases in the air discovered?
2. Why were the inactive gases discovered last?
3. What are the properties of oxygen?
4. What happens when a fuel burns?
5. Why is the air called a mixture?
6. What is an element? A compound? Name three elements; three compounds.
7. How do mixtures differ from compounds?
8. How is the composition of air affected by the burning of a fuel?
9. What three conditions must exist before you can have a fire?
10. What chemical change occurs during the rusting of iron? How can this rusting be prevented?
11. What are the products of combustion of the common fuels? Explain how each product is formed.
12. Distinguish between physical and chemical changes.
13. What are molecules?
14. What is oxidation? How may the rate of oxidation be increased? Decreased?
15. How are fuels classified?
16. What theories are used to explain how coal and petroleum were formed?
17. How is coal gas made?

18. How are charcoal and coke made?

19. What are the six main causes of destructive fires?

20. What methods are being used to decrease the danger of forest fires?

21. What methods are used to put out small fires such as may occur in homes or small buildings?

22. How can oil fires be put out?

23. What are the regulations in your city regarding the construction of buildings in congested areas?

24. In what different ways may fires get started in your home and in your school building?

SPECIAL REPORTS AND PROBLEMS

1. Make a collection of the different forms of carbon.

2. Make a collection of five oxides. What use is made of each oxide?

3. How may fires be started without a match?

4. Explain the action of the pump type of fire extinguishers.

5. How do Boy Scout campers and others prevent forest fires?

6. How to win a Boy Scout Merit Badge in firemanship.

7. Make a report on fireproof materials.

8. Does a rusting tin can gain in weight? Prove it experimentally.

9. How can small fires be put out?

10. How are buildings made fireproof? Are they absolutely fireproof or will they burn slowly?

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: atmosphere, mixture, element, compound, oxidation, combustion, kindling temperature, chemical change, physical change, oxide, combustible, incombustible, flame, fire, slow oxidation, rapid oxidation, spontaneous combustion?

2. In what different ways are fuels ignited at the present time? Consider gas engines, gas furnaces, oil burners, and wood and coal fires.

3. Why is the match such an important invention?

4. A combustible gas may be heated to its kindling temperature by compression. This is the method used in Diesel engines. Explain how the temperature of a gas is made to rise by compression.

5. How is oxidation prevented or reduced for each of the following: an iron stove or furnace, iron or steel tools used within the home, garden tools, metal screens?

6. Why is it helpful for large numbers of people living close to each other to have

regulations regarding: kinds of fuels burned in homes, materials used in constructing homes, location of factories and industries?

7. What kind of fire department do you have in your community? How well is it equipped to put out both large and small fires?

8. What are the causes for the fires in your community? The fire insurance companies will provide this information. What proportion of these fires are due to ignorance? To carelessness? To unknown causes?

9. One of man's greatest discoveries is knowing how to make a fire. What activities do you take part in which depend on the making of a fire or the burning of a fuel?

10. A big cause of fires was removed when man invented the electric light bulb. This replaced candles and kerosene lamps in the home. But the use of electricity still results in many home fires. What common causes of these fires can you give which result from the use of electricity?

11. Fire drills in schools are not just time-wasters. Why should they be held regularly and what should you do when the firebell sounds?

12. Why are grass fires dangerous and what can be done to put them out?

13. Give the scientific facts or principles which explain the following occurrences or results:

a. Fires are put out by using extinguishers which make carbon dioxide.
b. A lighted match does not set a large block of wood on fire.
c. Coal does not burn when heated red-hot in a closed test tube.
d. Hot iron burns in oxygen but not in air.
e. Charcoal turns red-hot when heated, but it does not burn with a flame.
f. A paper waste basket filled with scrap paper starts burning two days after an oily rag is thrown in it.
g. A weak blast of air makes a small fire burn better, while a very strong blast blows it out.
h. Fires under certain conditions have extinguished themselves.
i. Magnesium weighs more after burning than it did before it was burned.
j. Gasoline is vaporized to make it burn.
k. Water thrown on oil fire spreads the fire.
l. Air is removed from an electric light bulb and a gas like argon is added.
m. Carbon monoxide is formed in a hot coal fire when the drafts are closed.
n. Hydrogen explodes when ignited with a match.
o. Two pieces of wood get warmer when rubbed against each other.
p. A candle which is a solid fuel burns with a flame.
q. Iron cans are coated with tin.
r. Gases with an odor are mixed with water gas before burned in the home.
s. Water is used to put out wood fires.
t. Soot is formed on a cold glass dish when it is lowered over a candle flame.
u. Metals like aluminum and tin protect themselves when exposed to the air.
v. The inside part of the windows in a kitchen becomes covered with moisture after the gas stove has been burning for some time.

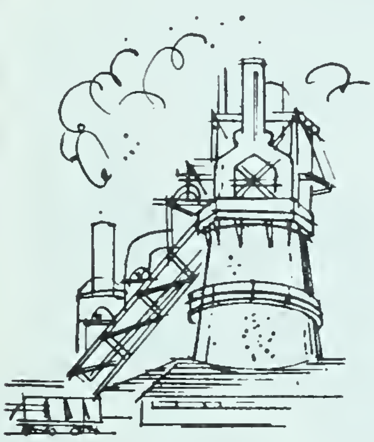
The old

EARLY MAN FIRST BUILT FIRES TO HEAT HIS HOME, TO COOK his food, and to protect himself from wild animals. Rapid progress in the use of fire was not made until man discovered the true nature of burning and had a better understanding of the nature of heat.

Toward the end of the 18th Century, Lavoisier discovered that oxygen was needed for burning and that the products of combustion weighed more than the original fuel. As a result of the discovery of oxygen and its part in burning, the other gases in the atmosphere were discovered. Thereafter man discovered better ways of burning fuels, and he invented improved methods of starting fires.

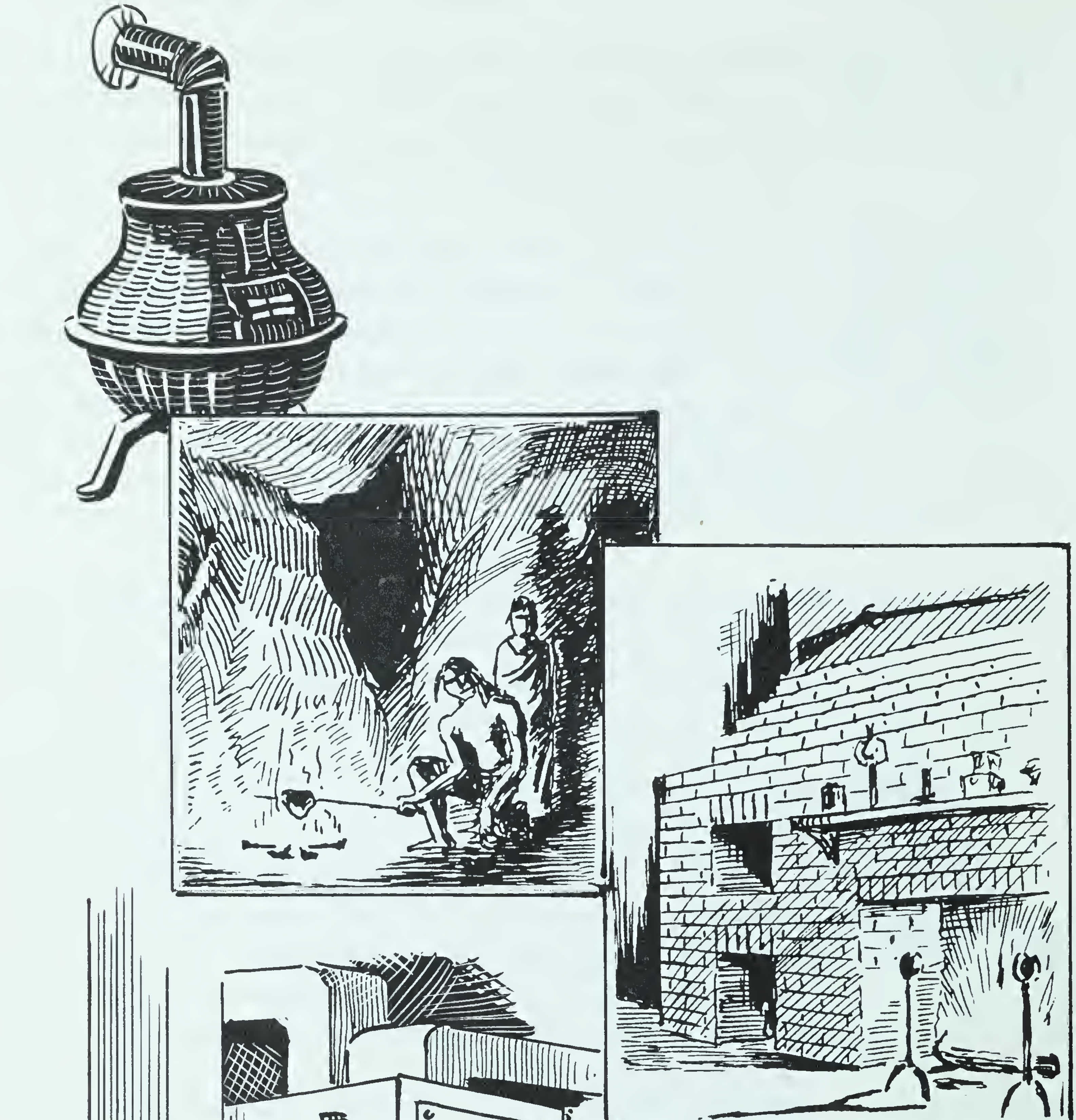
The new

THE DISCOVERY OF THE NATURE OF BURNING HAS MADE POSsible the invention of stoves, hot-air furnaces, blast furnaces, the new oil and gas furnaces, and automatically controlled burners of all kinds. Now you can keep your homes warm, cook your food, and ventilate your homes. You can protect yourself from the cold weather with the help of instruments which are easily adjusted and regulated by automatic controls.



However, there is still room for great improvement in the efficiency of our heating systems and engines. Too much of our fuel is being wasted unnecessarily. Then, too, we have many destructive fires which we could easily prevent by being careful and taking advantage of new discoveries. We need new fireproof materials for building our homes. We also need materials which will help us to conserve heat in our homes and other buildings more efficiently.

Scientists predict that many of our houses will be heated with the sun's energy in the near future. The heat of the sun will be stored in the daytime by the melting of some chemical or by absorption of the sun's heat with dark materials. Then, when the sun is not shining, the stored-up heat will be used to heat the houses.



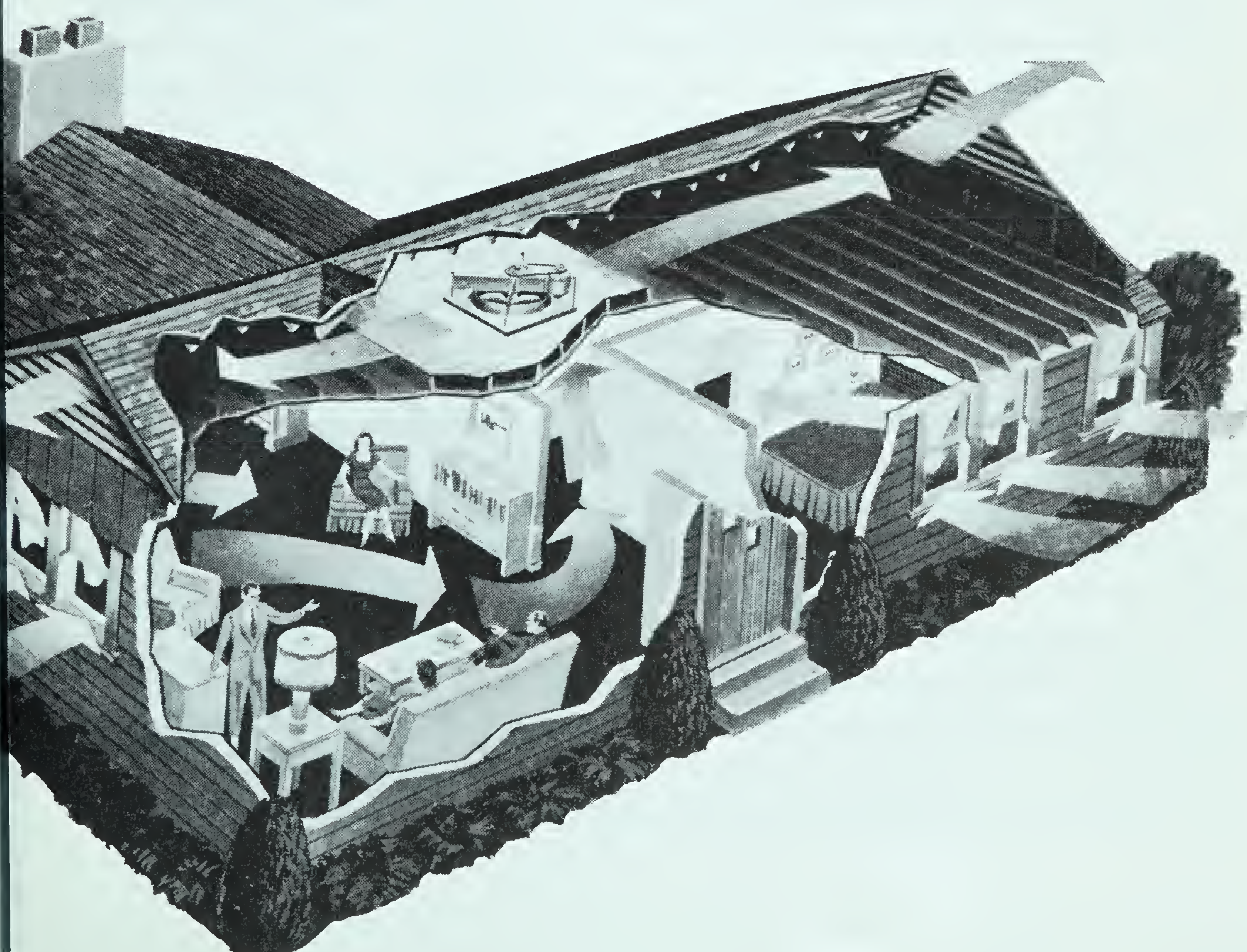
UNIT 4

How has man learned to heat and air-condition his home?

DISCOVERY AND PROGRESS

EARLY man actually lived in his stove. When his fire was first brought into his shelter, it was still an open fire. Later he cut a hole in the top of the tent or hut to make a chimney. The word *stove* originally meant *heated room*.

The ancient Egyptians and Greeks used this method of heating homes. Even when they had more than one room in their houses, they had a fire in only one room. Later the Romans used a *fire room* built in the cellar. The heated air was directed to different



parts of the house by pipes made of baked clay. Several rooms could thus be heated with one fire.

By the year 1,000 the English had improved room-heating by building their fires at one side of the room, allowing the smoke to escape through a hole in the wall. They put a short hood over the fire to direct the smoke toward the opening. They soon discovered that the higher the hood extended, the better the fire burned because of the better draft. Thus, a real chimney was invented. In time, a recess was made in the wall for the fire.

For hundreds of years fireplaces were the common means of heating houses. They were not economical because much of the heat went up the chimney. Nor were they very comfortable since one had to be near them for warmth.

Benjamin Franklin, in 1742, put metal around the top and sides of his fireplace, and noticed that the metal gave off more heat than the old fireplace. In his experiments, he developed an iron boxlike stove, with a grate for the fire. Originally, he put it in the fireplace so that the smoke would go up the chimney. Later the stove was moved out and a pipe carried the smoke away.

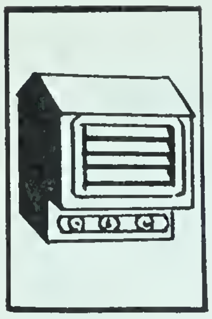
The stove eventually was put in the cellar and the heat directed up to the rooms. The use of hot water and steam instead of hot air marked another step in the progress of heating.

The first gas burner was described by Robert Bunsen in 1857. It mixed air and gas before the gas was burned. This discovery made possible the gas stove and gas burners of all kinds. The first gas stove was shown in the United States in 1876 and was the sensational feature of a baking demonstration. The oven was a small handmade iron box which was heated by yellow flame burners like torches. Before this, gas had been used for lighting, but not for cooking or heating.

Early man, with his poorly built house, did not need to provide ventilation . . . nature did it for him. Because our houses today are more tightly constructed, we need fresh air circulating through them. Good ventilation was made possible by the discovery of the properties of gases in air.

When Galileo noticed in 1592 that most substances expand when heated and contract when cooled, he made his first thermometer. This was a hollow glass bulb filled with air, fitted into a glass tube containing water. When the air in the bulb was heated, the water was pushed down the glass tube into the dish in which the tube rested. Many small changes were made in thermometers until the 18th Century, when Fahrenheit, a German scientist, made his thermometer which is in common use today. Later the Centigrade scale for measuring temperature was devised.

Modern methods of heating and ventilating homes have made use of the fact that heat will not pass through some materials easily. Such materials are called insulators. Asbestos is used to cover pipes, and rock wool to fill in spaces in the walls. Dead air spaces are often used within walls and between windows.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How did ancient people heat their homes? **2.** What fuels did they use? **3.** When and by whom was the stove invented? **4.** What are the different sources of heat? **5.** What are the effects of heat on matter? **6.** How do stoves and furnaces help to provide a continuous supply of fresh air? **7.** What is the purpose of the Bunsen burner? **8.** How is heat transferred from one place to another? **9.** How do we measure temperature? **10.** What are the different units of heat? **11.** How can fuels be burned more efficiently? **12.** Why must we ventilate our houses? **13.** What are the possible future developments in the heating of houses? **14.** How is the modern house air-conditioned?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

British thermal unit .	(Btu) the amount of heat needed to raise the temperature of one pound of water one degree on the Fahrenheit scale.
calorie	(*kal*-oh-ree), the amount of heat needed to raise the temperature of one gram of water one degree on the Centigrade scale.
conduction	(kon-*duk*-shun), the transfer of heat by two objects in contact, or between parts of the same object.
convection	(kon-*veck*-shun), the transfer of heat by the natural motion of gases and liquids.
humidity	(hew-*mid*-ih-tee), the moisture content in the air which is in the form of water vapor.
insulator	any material which does not conduct heat readily.
radiation	(ray-dee-*ay*-shun), the transfer of energy through space by vibration or by wave motion.
relative humidity . . .	the quantity of water vapor in the air compared to the water vapor the air could hold at that temperature.
temperature	the degree of heat which is measured on some definite scale.
ventilation	the continuous movement of fresh air in a room.

A What are man's sources of heat?

The most important source of the earth's heat energy is the sun. Scientists estimate that more than 95% of the earth's energy comes from the sun. Tropical regions get a large amount of heat all year 'round. Other regions get less, the amount decreasing toward each pole. Thus artificial heat is needed in some regions for at least a part of the year.

Glass bricks used in houses show how the direct rays of the sun can be used for heating. The sun's rays pass through the glass into the house. There the rays are absorbed and raise the temperature of the rooms.

Heat produced by burning fuels also comes indirectly from the sun. Thousands of years ago heat energy from the sun caused forests to grow rapidly. Our coal and oil today come from the remains of these ancient forests.

Heat is produced by a chemical change when fuels are burned. Most of our artificial heat is obtained by burning fuels. The type of fuel burned in any locality depends on the supply available and the cost. Where wood is cheap, it may be the common fuel. In cities, coal, oil, and gas are most frequently used.

The amount of heat which a certain quantity of fuel produces is not always the same. Some heating systems are very inefficient. They do not mix air properly with the fuel. They also lose much heat in transferring it to the various parts of the house.

Heat is produced by friction. Your hands get warm when you slide down a rope. The wheels of a freight car become hot when they slide on the rails. When you strike a match, it lights because of friction.

The molecular theory explains the heating of materials by friction. According to this theory, the temperature of a substance is determined by how fast its molecules move. Heating any material, therefore, increases the movement of its molecules. In rubbing materials together we make their molecules move faster. This is the reason why friction produces heat.

Fig. 4-1. A Boy Scout uses friction to produce heat for starting a fire.

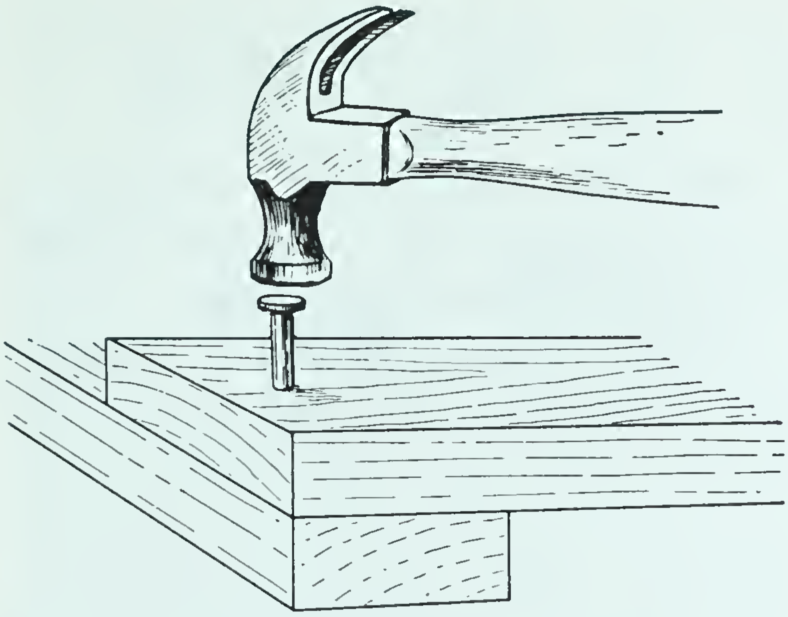


Fig. 4-2. When you pound a nail into wood, the friction causes the nail to become hot.

PUPIL ACTIVITY

Drive a nail into a thick board, leaving the nail head projecting slightly. Quickly pull the nail out of the board with a clawhammer. Feel the nail. Result? Conclusion?

The amount of heat produced by friction depends on the kinds of materials that are rubbed together, the smoothness of these materials, the length of time they are rubbed together, and the force with which they are rubbed together.

Heat is produced when an electric current flows through a material that has resistance. Electrical appliances, such as toasters, irons, and heaters, contain wires that offer resistance to an electric current. The *resistance* of a wire to an electric current may be compared to the friction produced by water flowing through a long, thin pipe. The longer and thinner the pipe is, the more resistance there will be. In the same way, a long thin wire has greater electrical resistance than a short thick one, provided both wires are made of the same metal.

The resistance of some wires increases as their temperature increases. The composition of the wire itself is also important. One of the common materials used in electrical heating appliances is *nichrome* (*ny*-krome), an alloy made of nickel and chromium.

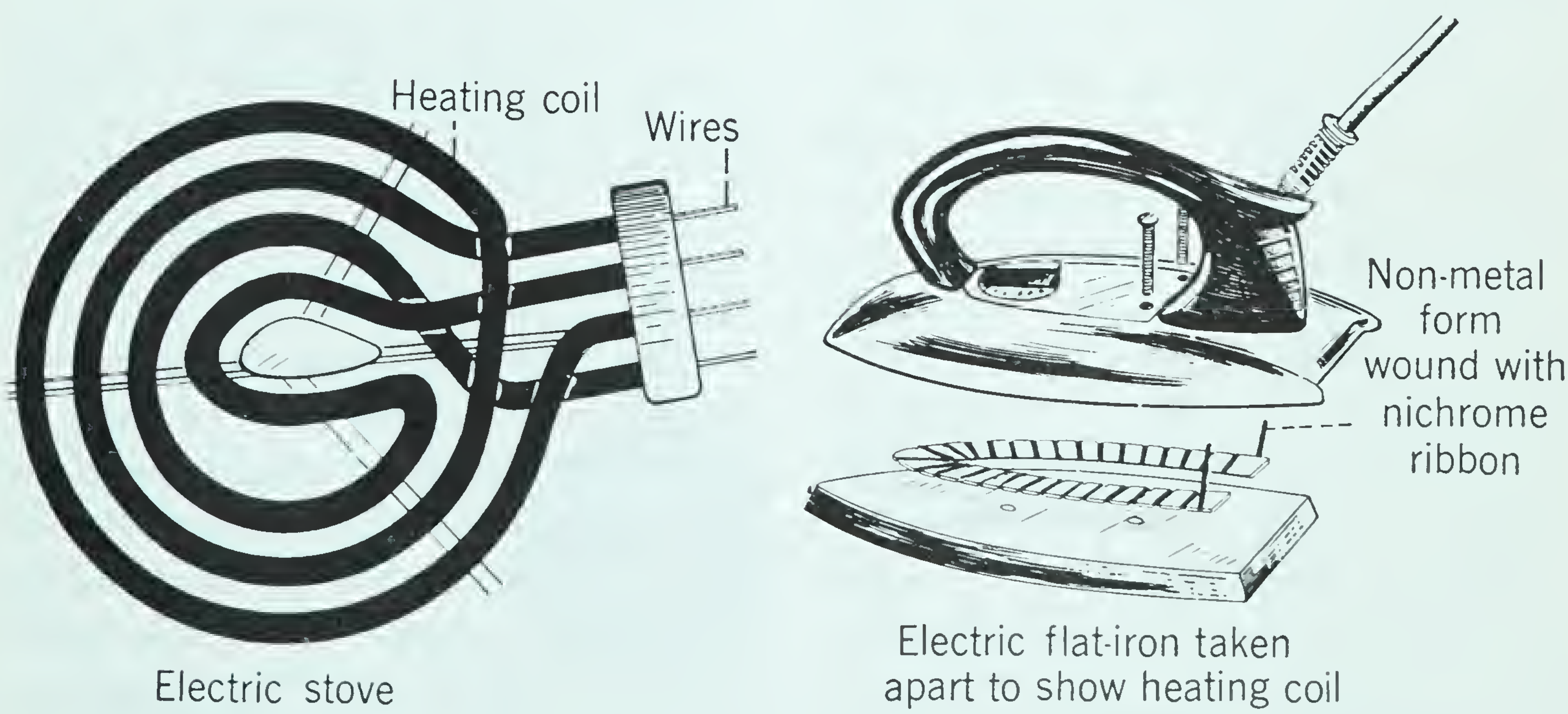


Fig. 4-3. Electric appliances like an electric heater or iron, have wires that are resistant to an electric current. The resistance causes them to get hot.

The heating element is usually coiled to concentrate the heat in a smaller space.

Electricity is still too expensive to use in heating most houses. However, radiant heating by electricity is coming into use in some of the newer houses.

REVIEW QUESTIONS

1. From what source does the earth get most of its energy? **2.** What is the original source of the heat energy in fuels? **3.** How do you explain the production of heat by friction? **4.** What appliances produce heat by the flow of electrical current through coils of wire?

B How are temperature and quantity of heat measured?

Temperature and quantity of heat mean different things. We have used the molecular theory to explain friction and the transfer of heat from one object to another. This theory also helps to explain the difference between temperature and the quantity of heat.

Temperature means the degree of heat or cold of any substance. This is determined, as we have explained, by the movement of its molecules. The quantity of heat in a substance depends on three factors: (1) its temperature; (2) the kind of substance; and (3) the amount of the substance. For example, it requires more heat to keep your school at a certain temperature than it does to keep your home at the same temperature. Explain why this is so.

Because temperature and quantity of heat are different, we must use different units to measure them.

A thermometer is needed to measure temperature. If you go into a deep cellar or cave on a warm summer day, you will feel cool. But if you go into the same cellar or cave on a cold winter day, you will feel warm. A room often seems hot after you have been out in the cold air, although it seems chilly after you have been sitting in it for a while.

PUPIL ACTIVITY

Select three basins, A, B, and C. Fill A with cold water, B with hot water, and C with warm water. Hold one hand in A and the other in B for a few minutes, then transfer both hands to C. How does the water in C now feel to the hand from A? To the hand from B? Can you depend on feeling to determine temperature? Explain your answer.

Hold your hand successively against a number of different objects such as metal and wood. How do metals feel compared to wood? Are they really at a different temperature if in the same room? Explain your answer.

You can see how necessary a thermometer is, not only because of your curiosity about the temperature in a room, but also for practical reasons. For best results, a baker should know the temperature of his oven before he begins his baking. The doctor uses a thermometer to take the temperature of his patient to see if he

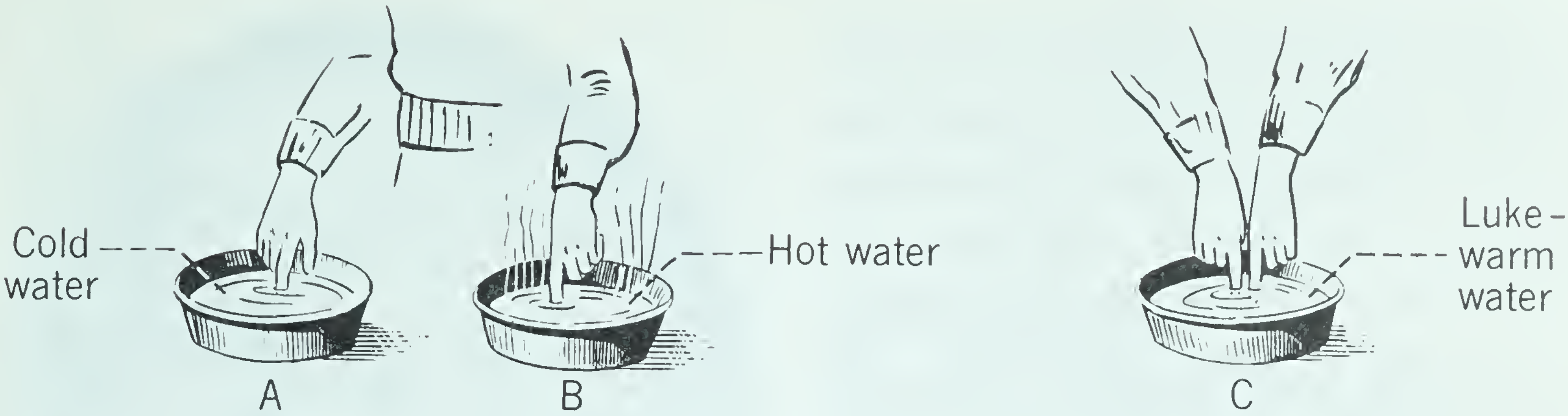


Fig. 4-4. Since the sense of feeling is comparative, it is hard to judge temperatures.

has a fever. In what other ways is a thermometer used?

The operation of the thermometer is based on the tendency of materials to expand and contract. Most materials expand when heated and contract when cooled. An object is said to *expand* when it becomes larger without any gain in weight, and is said to *contract* when it becomes smaller without losing weight.

DEMONSTRATION

(A) Fasten a toy balloon on the open top of a flask. Heat the flask. Result? Conclusion? (See Fig. 4-5.)

(B) Fill a second flask with colored water. Fit a glass tube a few inches long into the stopper in the flask. Heat the flask. Result? Conclusion? Allow to cool. Result?

(C) Heat two pieces of different metals welded together. Result? Explain your answer.

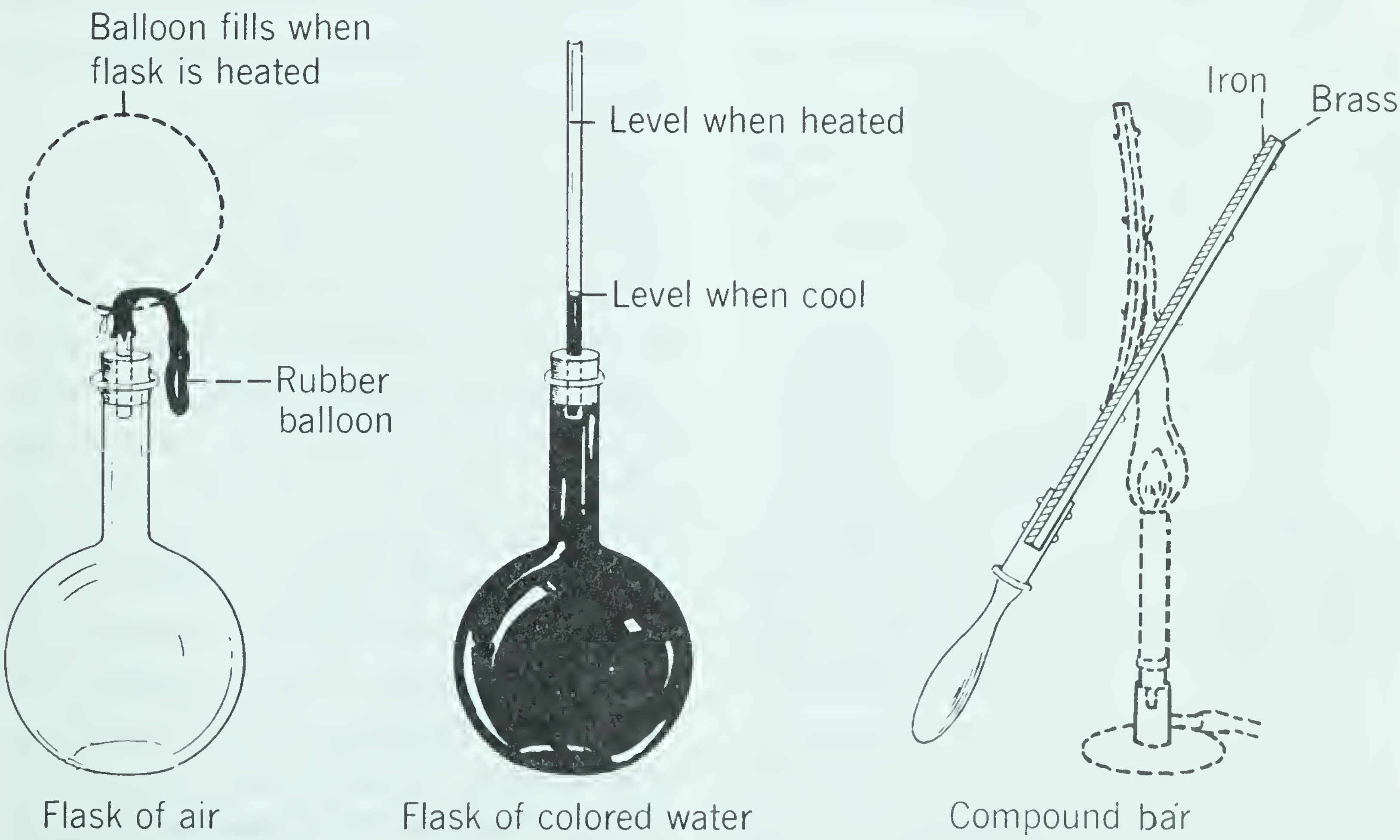


Fig. 4-5. Gases, liquids, and solids expand when heated and contract when cooled.

When air in the flask was heated, the molecules of the gases in air moved faster and as a result required more space. In this way the volume was increased and the air expanded. Although air is not used in thermometers now, other gases, like hydrogen, are used in some very accurate thermometers. However, the same principle is involved.

When the water in the flask was heated, the motion of the molecules was increased and they spread farther apart. Then the water expanded and occupied a greater volume, so that the water was forced to rise in the tube. Fig. 4-6 shows that the molecules in a flask of hot water are farther apart than in a flask of cold water. If a flask is heated enough, the water will expand until it entirely fills the flask. If heating continues, the water will overflow.

If you heat a compound bar, made as shown in Fig. 4-5 by welding together two pieces of different metals, you will note that both metals expand. However, the heat makes the molecules in one metal move faster and farther apart than the molecules in the other. The bar bends, as a result, because of this difference in expansion of the two metals. This unequal expansion of two metals is the principle used in the *thermostat*, a device used in regulating temperatures.

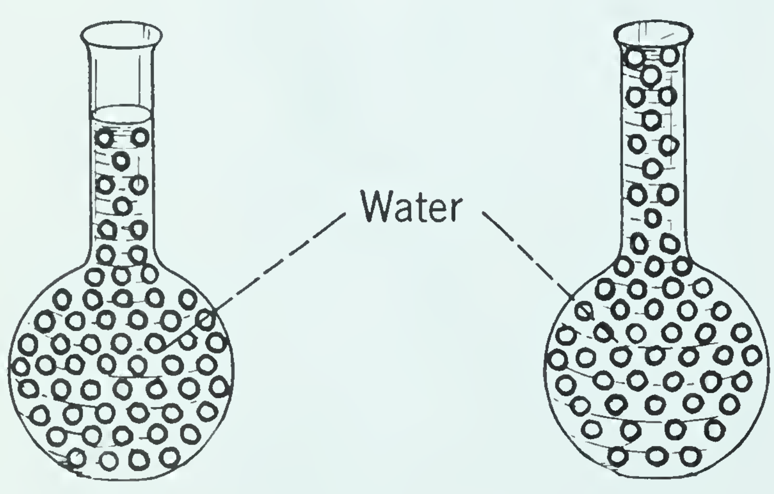


Fig. 4-6. Note how the molecules in the heated flask spread farther apart.

Fig. 4-7. A thermostat is used to control the burning of a fuel in a furnace. It can also control the temperature in a refrigerator and an electric iron.

The expansion and contraction of solids caused by changes in temperature creates many problems. Railroad tracks must be laid with small spaces at the ends; sections of concrete highways have tarred joinings between them. Why? For the same reason, telephone, telegraph, and electric light wires are always put up with a slight sag between the supports. Metal screw caps are more easily removed from glass containers if we hold the cap under hot running water. This is because metal expands faster than glass.

Our modern thermometers use the expansion of liquids. However, water

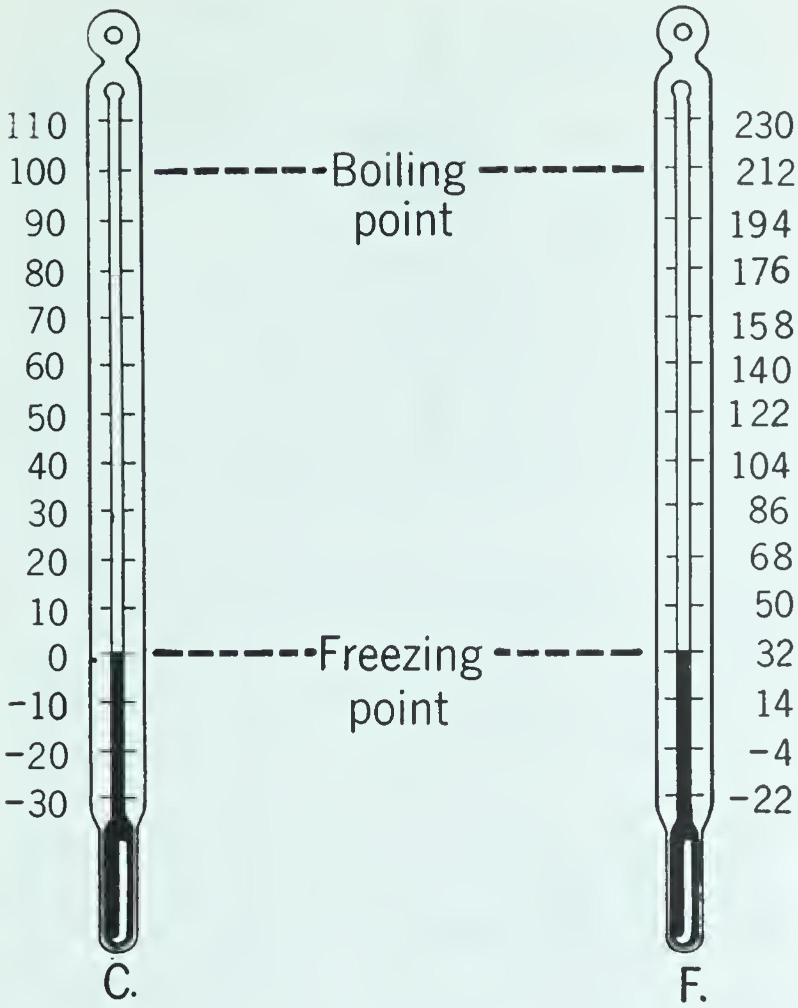


Fig. 4-8. Both Centigrade and Fahrenheit scales use the boiling and freezing temperatures of water as the fixed points.

is one liquid which is not used in thermometers. One reason it is not used is because of the high freezing temperature of water. In addition, water is an exception to the general rule that substances expand when heated and contract when cooled. If you take a container of water which is at room temperature and cool it, it will contract until it reaches 39.2° Fahrenheit. The water then expands when cooled from 39.2° to 32° Fahrenheit, or its freezing point.

Modern thermometers usually contain alcohol with red coloring added, or mercury, which has a silvery color. The thermometer scale most commonly used in English-speaking countries is the ***Fahrenheit*** (*far*-un-hyte) ***scale,*** which was first devised by the German scientist Fahrenheit in 1714. The people of Europe and scientists in laboratories use another scale called the ***Centigrade*** (*sen*-tee-grade), which was developed in Sweden in 1742.

PUPIL ACTIVITY

Examine a thermometer at home or at school. Which scale is it, Fahrenheit or Centigrade? How is it made? What substance is used in the bulb? Why is this substance used? Why is the bore or hollow portion of the tube so small? Why is the top of the tube closed?

Blow gently on the thermometer bulb. What happens to the mercury or alcohol? Put a cold object on the bulb. What happens? What causes the movements of the mercury or alcohol column?

To change Centigrade readings to Fahrenheit, add 40 to the Centigrade, *multiply* the sum by 1.8 and subtract 40. To change Fahrenheit to Centigrade, add 40 to the Fahrenheit, *divide* by 1.8 and subtract 40. Change 68° F. to ° C.; 68° C. to ° F.

The thermometer measures temperature in degrees. You can find the freezing point of water on a thermometer by putting the bulb in melting ice or snow (see Fig. 4-9). The resulting height of the mercury in the tube is marked 0° on the Centigrade scale and 32° on the Fahrenheit scale. To determine the boiling point, put the bulb in steam from boiling water (see Fig. 4-10). The height of the mercury is marked 100° on the Centigrade scale and 212° on the Fahrenheit scale. Note, however, that the boiling point of water varies with the air pressure. Water boils at 100° C. and 212° F. *only when the barometric pressure*

is 760 mm. or about 30 in. of mercury.

The space between the freezing and boiling points is divided evenly into units called ***degrees.*** When a scale is divided evenly into units this way it is graduated. You can see that a Fahrenheit degree is different from a Centigrade degree by doing the following.

PUPIL ACTIVITY

Examine a Centigrade thermometer. Where is the freezing point of water? How many degrees are between the freezing point of water on a Fahrenheit scale and the boiling point of water? On a Centigrade scale? Is a Centigrade degree larger or smaller than a Fahrenheit degree? How many Fahrenheit degrees will make one Centigrade degree?

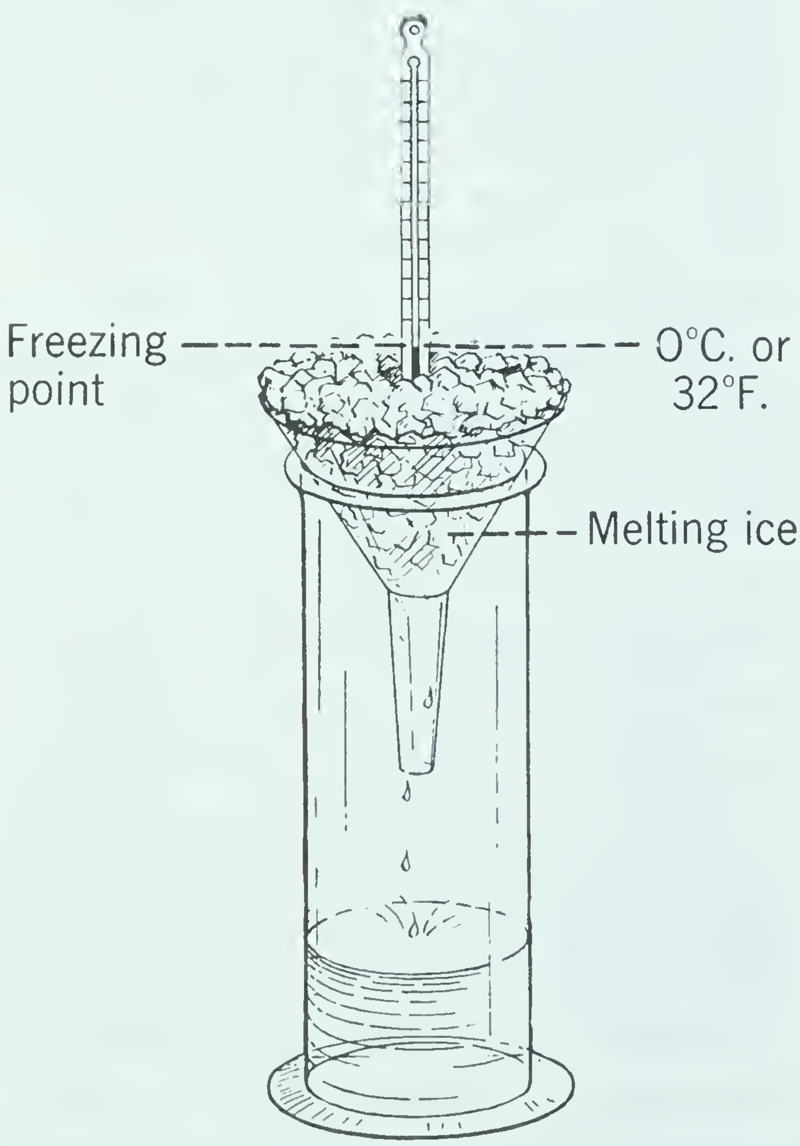


Fig. 4-9. By putting the bulb of a thermometer in melting ice, you can find the freezing point of water.

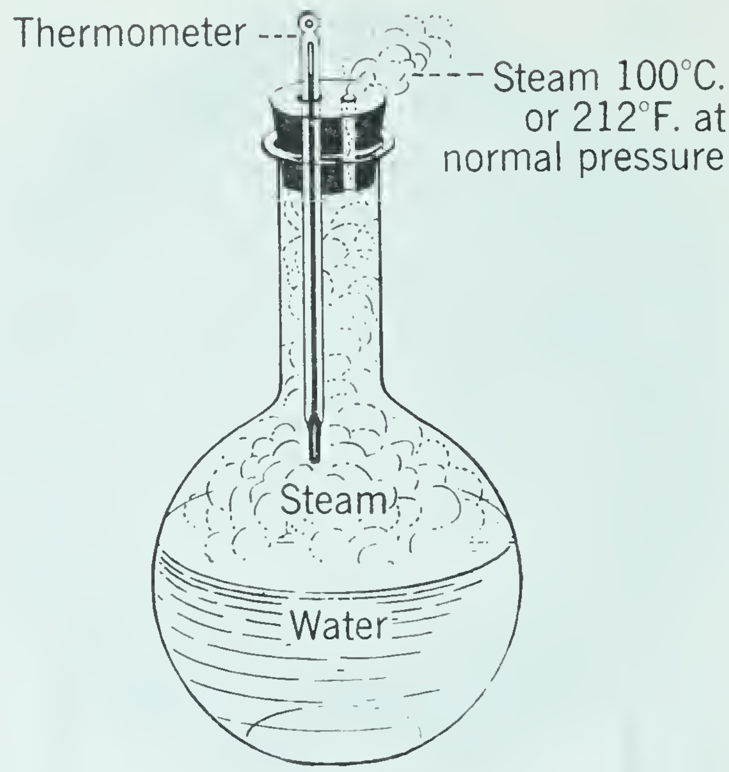


Fig. 4-10. You can determine the boiling point of water by putting the thermometer bulb in boiling water or steam. The boiling point is lower at higher altitudes where the barometric pressure is less than 760 mm.

The quantity of heat can be measured in British thermal units (Btu's). One *Btu* is the amount of heat needed to raise the temperature of one pound of water (about one pint) one degree on the Fahrenheit scale.

DEMONSTRATION

Measure out one pound (one pint) of water in a large beaker. Take its temperature. Heat the water for three minutes. Again take its temperature.

Now measure out two pounds (two pints) of water in another large beaker. Take its temperature. Is the temperature the same as that of the water in the first beaker? Heat this second beaker, using the same burner, until the temperature is the same as that of the one-pound lot of water. Does it take longer? Does it contain the same amount of heat? Are temperature and the amount of heat the same? Explain.

If the temperature of one pound of water is raised 10° on the Fahrenheit scale, it has absorbed 10 Btu's of heat ($10 \times 1 = 10$). If two pounds of water are heated from 40° F. to 60° F., they have received 40 Btu's ($20 \times 2 = 40$). How many Btu's of heat are needed to raise the temperature of one pound of water 32° F. to 212° F.?

The amount of heat that the water has absorbed in heating is set free when it cools to the original temperature. Thus, heat energy can be stored in heated water, transferred, and then recovered for use as the water cools.

Heat can also be measured in units called calories. The *small calorie* is the amount of heat needed to raise the temperature of one gram of water one degree on the Centigrade scale. It takes 100 calories of heat to raise the temperature of 10 grams of water 10° on the Centigrade scale. For many purposes, this calorie is too small a unit. Therefore, in measuring the energy value of foods, the *large Calorie* is used. It is equal to 1,000 small calories, and is the quantity of heat needed to raise the temperature of 1,000 grams (about one quart) of water one degree on the Centigrade scale. The small calorie is used in most laboratory experiments. If you go on to study chemistry or physics, you will use this measurement.

REVIEW QUESTIONS

1. What is the difference between temperature and quantity of heat? **2.** Why is the sense of feeling not reliable enough for taking temperatures? **3.** Why is water a poor liquid to use in a thermometer? **4.** How are our modern thermometers made? **5.** How are the fixed points on the Centigrade and Fahrenheit thermometers obtained? **6.** What is the unit of temperature? Is this unit the same on all thermometers? **7.** What are the units used to measure quantity of heat? **8.** How is each defined? **9.** How many calories of heat are needed to raise the temperature of 75 grams of water from 60° C. to 90° C.? **10.** How many Btu's of heat are set free when 20 lbs. of water are cooled from 70° F to 40° F.? **11.** Under what conditions can water boil at a lower temperature than 100° C.?

C How is combustion regulated in a stove or furnace?

The draft caused by a fire supplies air and removes the gaseous products of combustion. You have already learned that a fire needs air. You have also learned that the compounds, carbon dioxide and water, are formed during combustion. From the following demonstration, you can see how a stove gets its supply of air and how the products of combustion are removed from a stove.

DEMONSTRATION

Put four match sticks beside a candle. Light the candle and put a chimney over it so that it rests on the sticks as shown in Fig. 4-11. Cover the top of the chimney. Result? Conclusion? Hold a paper above the chimney. Does smoke move up or down? Test for currents at the base of

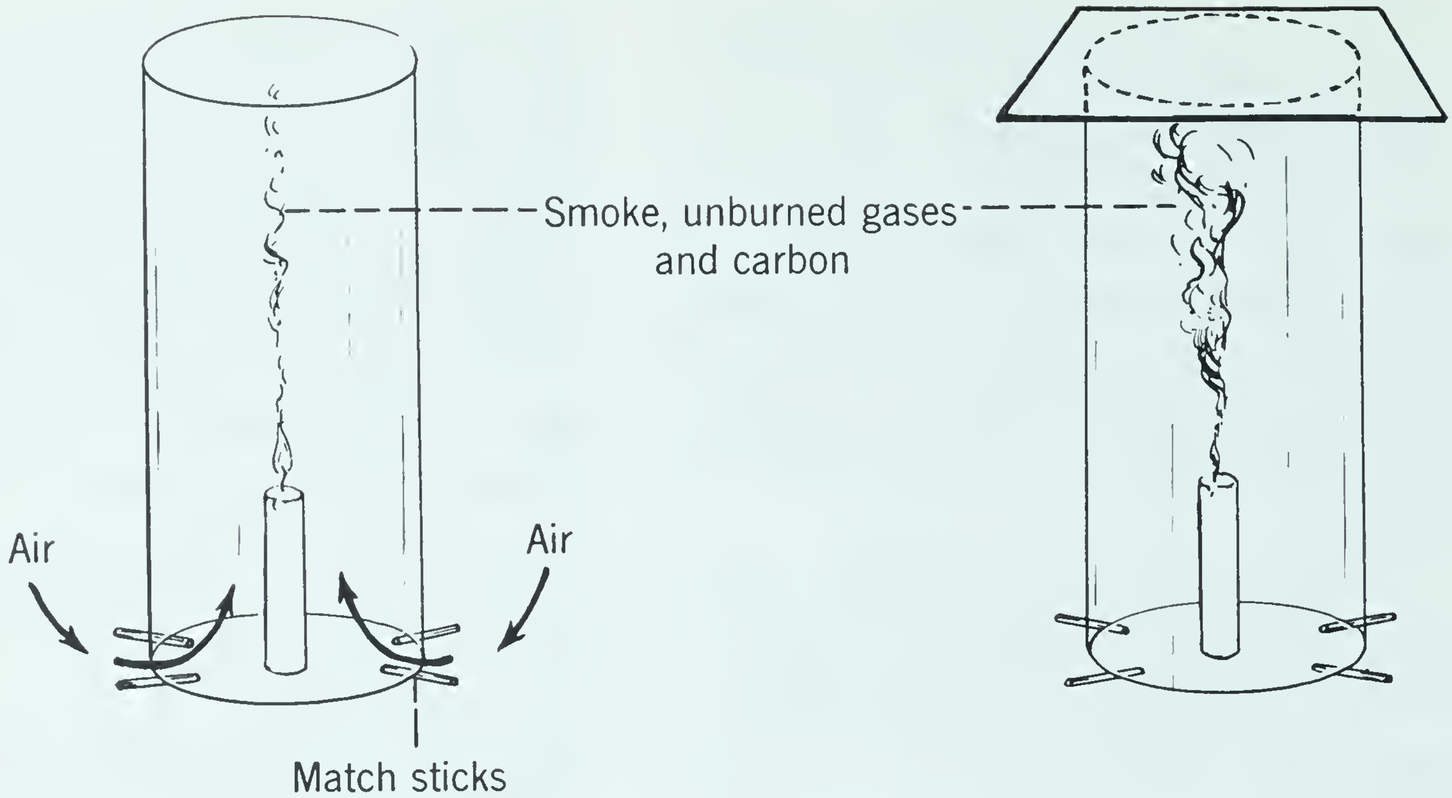


Fig. 4-11. A fire sets up a draft which provides a continuous supply of air. As the air rises, it carries with it products of combustion.

the chimney. Results? Compare with drafts in a fireplace chimney.

Evidently there is a current of air flowing in at the base of the chimney. This is called the ***draft.*** But why did the air not go in at the top of the chimney?

From this demonstration you can see why a fire creates its own draft. When the air around the flame is heated, it expands. Fewer molecules of gases are present in a given volume of heated air than in the same volume of cool air. This makes the warm air less dense than the cool air. Therefore, the warm air is pushed up by the cool air entering at the bottom.

This state of unbalanced air pressure makes a current of air which is known as a *convection* (kon-*veck*-shun) *current.* Cool air coming in at the bottom is continually being warmed by the flame and forced up. As it rises, it carries with it the carbon dioxide, water vapor, and other products of combustion (see Fig. 4-11).

A furnace can be regulated by a thermostat placed in any room of a building. Many furnaces are regulated by a thermostat. The method of operating a thermostat is shown in Fig. 4-12. An iron strip and a brass strip, which expand at different rates when heated, are firmly fused together in a rod. One end of the rod is fixed, while the other end is free.

We learned earlier in this unit that such a rod will bend when heated because of the unequal expansion of the two metals. Let us suppose that the air around the thermostat is heated. Since brass expands faster, the rod will bend away from the contact point and thus shut off the oil burner. When the air cools, the contraction of the metals bends the rod in the opposite direction so that it again touches the contact point and turns on the oil burner again.

Thermostats can be set for a considerable range of temperature. They

are used for heat control of oil and gas burners and automatic coal stokers in home and industry. An automatic refrigerator has a thermostat to keep the inside cold. It is connected to work in the opposite way from that shown in Fig. 4-12. That is, it turns on the freezing unit when the inside of the refrigerator is warm, and shuts it off as the temperature falls.

Gas burners operate by burning a mixture of gas and air. The gas range is a convenient device for producing heat quickly. It leaves no ashes and can be lighted easily, and is regulated to give the right amount of heat. A Bunsen burner is really a small gas stove. Let us see how it operates.

PUPIL ACTIVITY

Inspect the parts of a Bunsen burner. Use the drawing of a Bunsen burner in Fig. 4-13 to help you. Find the base with the gas inlet pipe, the spud or nipple, the collar, and the mixing tube. Unscrew the mixing tube and locate the inlet. (A) Connect the delivery tube to a gas outlet and light the gas. What sort of flame results? Hold a cool white dish in the flame. Result? (B) Turn off the gas. Replace the mixing tube. Turn the collar so that no air enters. Relight. Test the flame as before. Result? Note color and size of flame. Test with dish as before. (C) Change the mixing tube so that the burner gets plenty of air. Again note both the size and color of the flame. Test with the dish. (D) Scrape off some of this carbon already collected, and blow it from a piece of paper into the burner through the holes of the collar. Result? Explain. Where did the carbon come from? Which flame burned the carbon best and was therefore the hottest?

The efficiency of the Bunsen burner

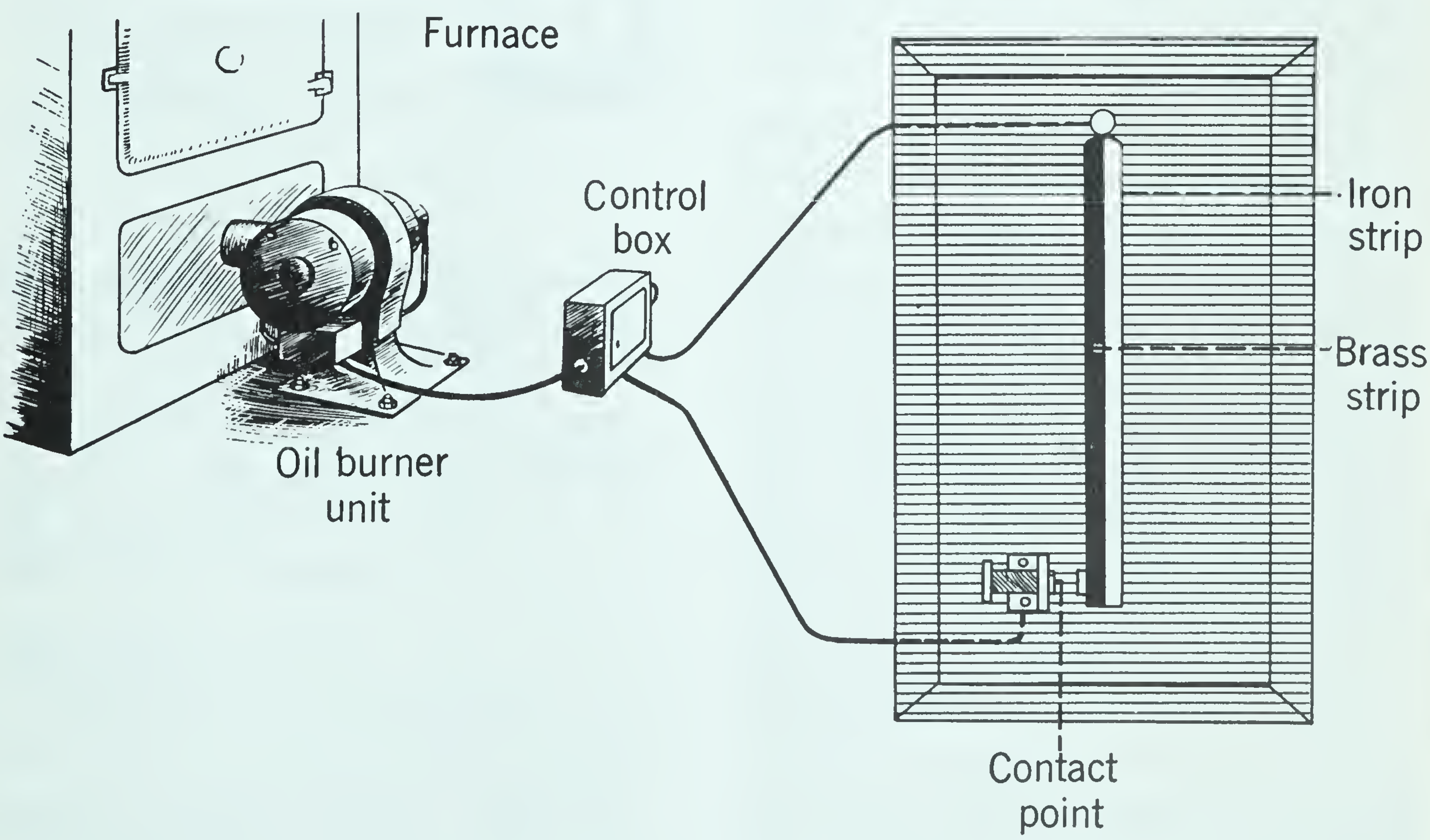


Fig. 4-12. In a thermostat, the unequal expansion of brass and iron when heated is used to regulate the temperature of an oil burner.

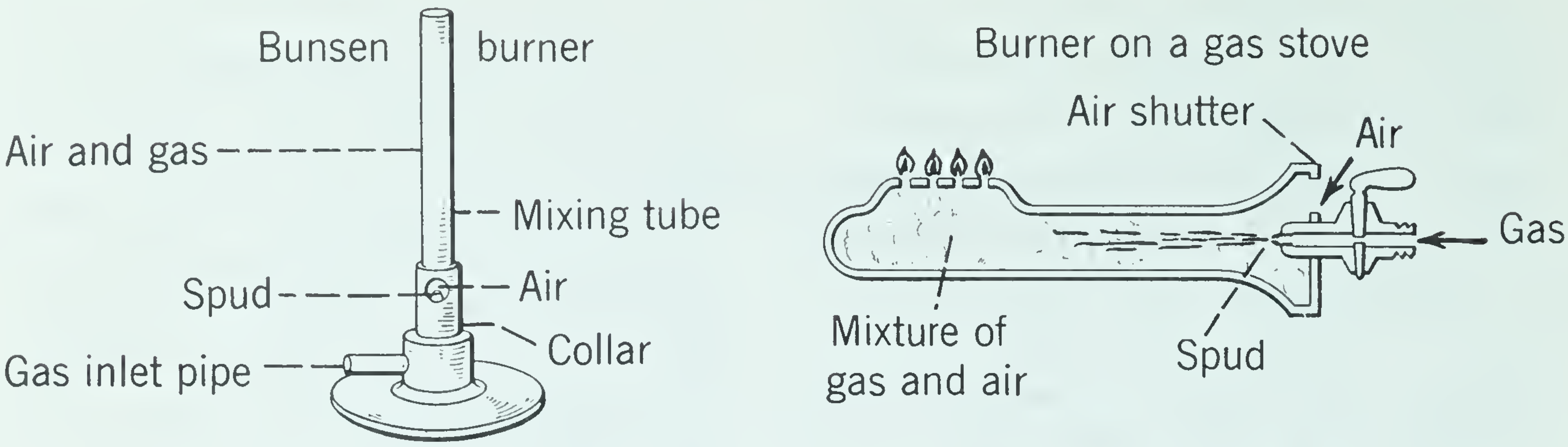


Fig. 4-13. A Bunsen burner and a gas stove operate on the same principle. Both depend on the proper mixture of gaseous fuel and air.

depends on the way in which air is mixed with the gas. If the collar is turned so that too little air is allowed to enter, the gas is not completely burned. Carbon is then given off as waste material. When the gas is properly mixed with air, however, no carbon is wasted and a hotter flame results.

The kitchen gas stove is really a large Bunsen burner. If you have a gas stove at home, examine it and find the *gas line,* the *air regulator,* and the *mixing chamber.*

Light the gas in the stove and note if the flame is yellow or blue. If it is yellow, ask the gas company to send a man to regulate the burners. A yellow flame means that some carbon is red-hot and for lack of air is not being completely oxidized or burned. The burners should always produce a blue flame. When the flame is blue, you are getting the greatest amount of heat from the smallest amount of gas. The gas stove is usually cheap to operate.

With your parents' permission, change the position of the air regulator on your gas burner. Notice the change in the flame. Set the regulator back when you are finished.

REVIEW QUESTIONS

1. What is a draft? **2.** What do we mean by convection? **3.** Explain how the thermostat works. **4.** Why is it important for the Bunsen burner to mix air and gas properly? **5.** In what ways is your kitchen gas stove like a Bunsen burner?

D How is heat transferred from one place to another?

Heat radiates in all directions from a heated object. You have felt the heat come directly to you when you were standing near a hot stove or fireplace. You have also felt the heat when you were standing in the direct rays of the sun. In both instances the heat has traveled from its source to you by a process called *radiation* (ray-dee-*ay*-shun). *Radiation* is the transfer of energy by waves or rays.

The sun and the stove are heated bodies which set up heat waves that travel in all directions. Some of these

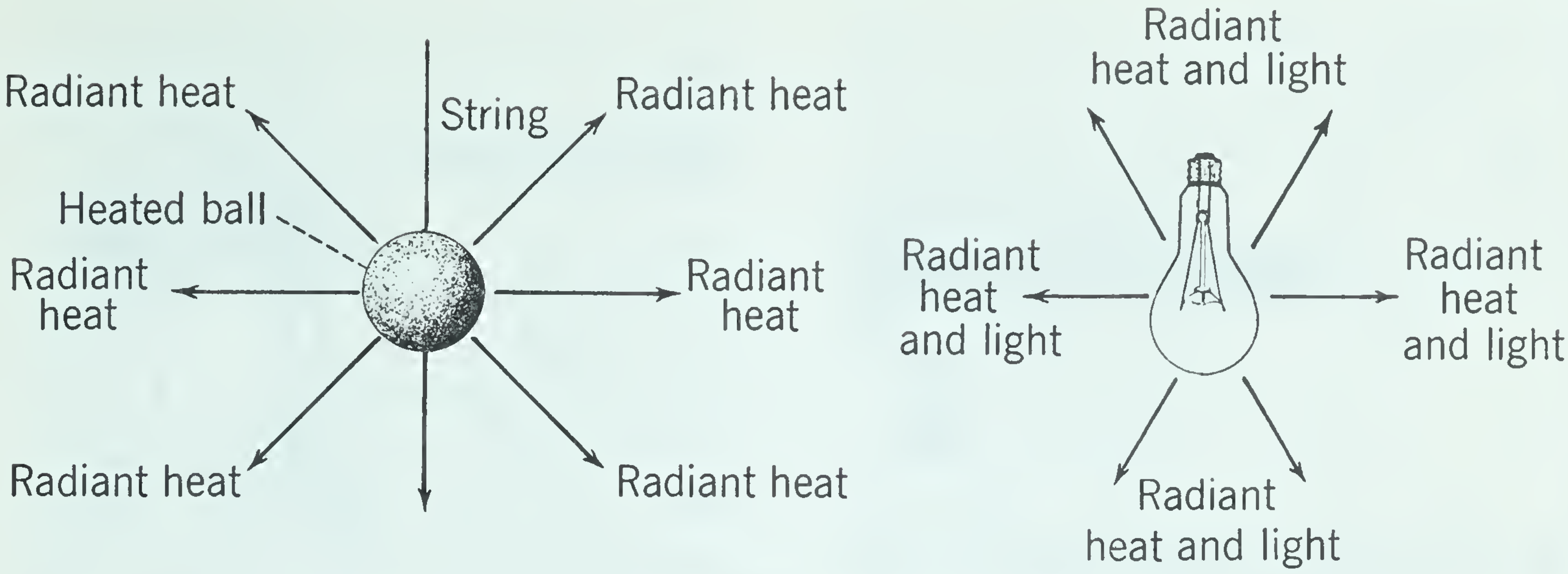


Fig. 4-14. Heat waves radiate in all directions from heated objects.

will pass through air, glass, and some other materials.

All these substances absorb some of the sun's energy and thus reduce the amount passing through. When a person is out in the open, part of the sun's radiation is prevented from reaching him by the air, but if the person sits on a glassed-in porch, even less radiation from the sun reaches him. Why?

The radiant energy from the sun makes the earth warm. The sun's radiant energy that is not absorbed by air strikes the earth and heats it. This raises the earth's temperature. The earth, in turn, radiates the heat received from the sun. Thus, the atmosphere receives most of its heat from the earth, and the air is usually warmer near the earth than it is at higher altitudes.

PUPIL ACTIVITY

Put your hand under, but not touching, a lighted electric light bulb. Can you feel the heat? Turn off the light. Result? Repeat the experiment by putting your hand at the side of the bulb.

The motion of the molecules of the lamp filament sets up heat waves. These are transferred to the molecules of your hand. When the molecules in your hand are set in faster motion, your hand feels warm.

Heat passes through matter by conduction. Have you ever picked up an iron frying pan and found that its handle was so hot you burned your fingers? How did the handle get so hot when no heat was applied directly to that end of the frying pan?

The passing of heat along or through a substance by molecular collision is *conduction* (kon-*duck*-shun). If you heat one end of an iron rod, the whole length of the rod gets hot. This is because iron is a good conductor of heat. Iron conducts heat about 100 times as easily as water, and about 2,500 times as easily as air. In general, metals are good conductors of heat, while liquids and gases are poor conductors.

When you heat one end of a rod, the speed of vibration of the molecules at that end is increased. The rapidly

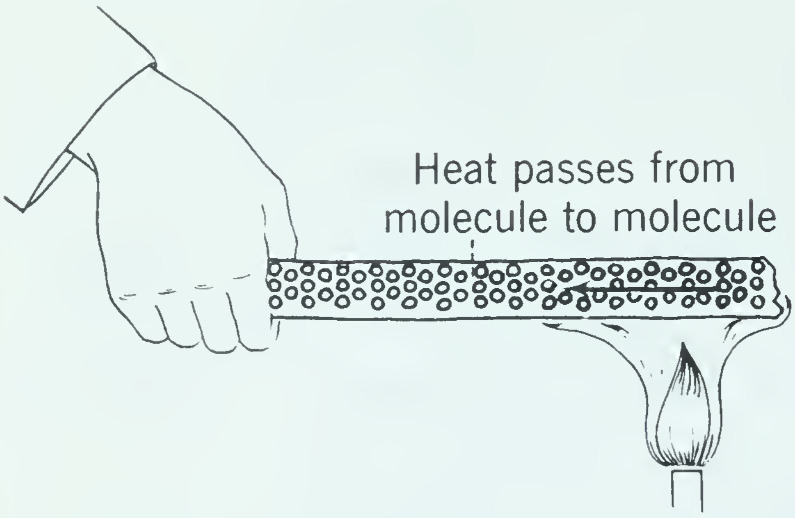


Fig. 4-15. Heat passes through this metal rod by the process of conduction.

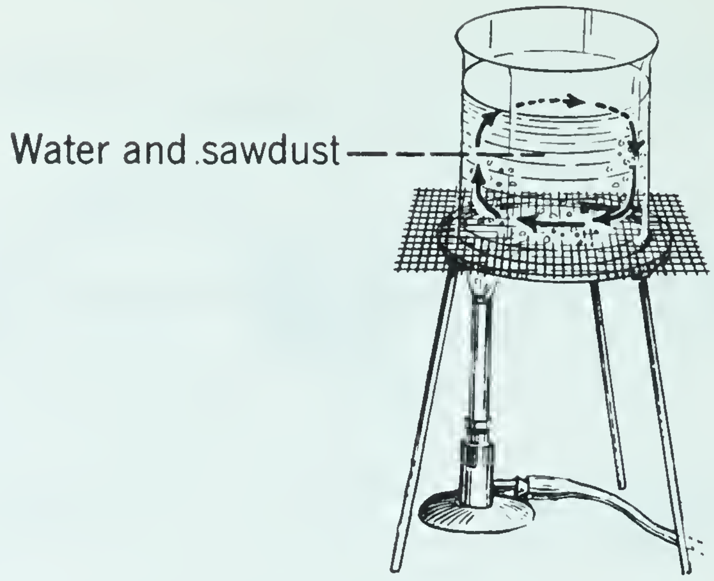


Fig. 4-16. Heat is transferred through the water by convection. The arrows show the path of convection currents.

moving molecules set other molecules near them in more rapid motion. If the rod is short, this goes on until the other end is reached. Although the molecules themselves do not move from one end of the rod to the other, the heat energy moves from one molecule to another until even the unheated end becomes quite hot.

Heat is transferred in liquids and in gases by convection (con-*veck*-shun). Heat cannot be transferred very far by conduction or by radiation in an ordinary heating system. It can be efficiently carried by circulating currents of air or water. We know that air and water expand when they are heated. In a room where there is a heater, the air near the stove is warmed by radiation and conduction. The heated air then expands in volume. This makes it less dense than the cool air whose molecules are still close together. As this warm air expands, cooler air moves in below it, forcing it to rise. This sets up a current of moving air which by its circulation carries heat to all parts of the room. The following experiment shows how this takes place.

DEMONSTRATION

(A) Light a Bunsen burner. Hold your hand over the flame and at the sides. Where does the air seem to be warmest? In which direction is the air moving above the flame? At the sides? Will warm air be moving up or toward the sides?

(B) Put some sawdust in a beaker of water and heat the beaker. In what direction does the sawdust directly over the flame move when one side of the beaker is over the flame? In which part

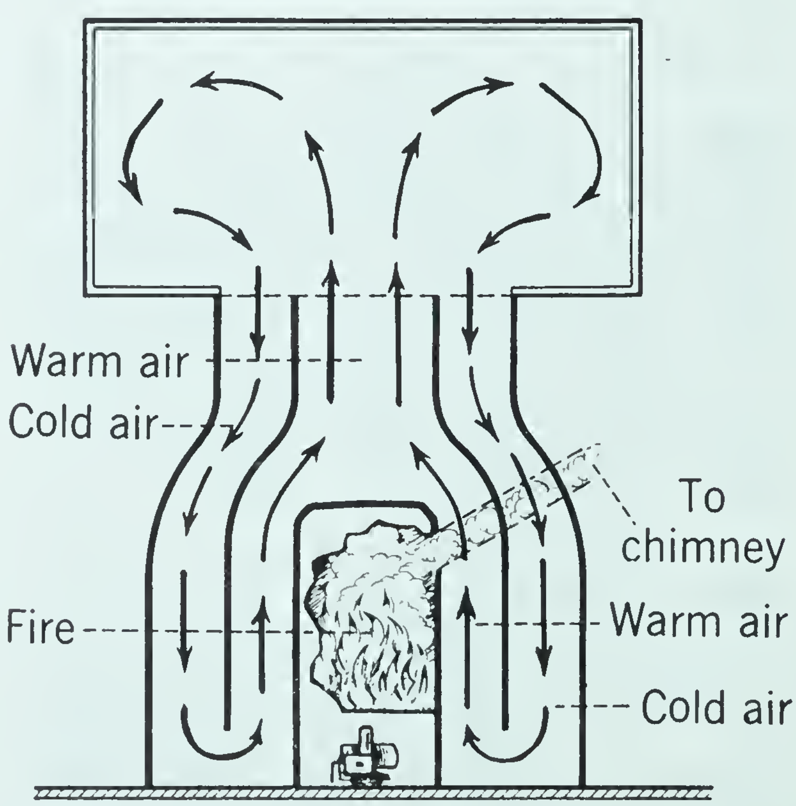


Fig. 4-17. This shows the operation of the pipeless hot-air furnace.

of the beaker does the sawdust move downward? Does the water seem to move in a complete circuit? In which direction does hot water move? The cooler water?

We call the transfer of heat by currents of air or water set up in this way ***convection.*** In a room, warmer currents of air move upward and are cooled. As they are cooled they get heavier and move downward. Then they are heated again. And so the process repeats itself.

When the air near the earth is heated, it gets lighter and rises above the colder air which is more strongly pulled down toward the earth by gravity. This is how gravity causes winds. Winds are really convection currents that begin with rising air currents over the warmer regions. Gravity is also the cause of the currents in the beaker of water, which made the sawdust circulate all through the beaker when it was heated.

Man has learned that heat is transferred by radiation, conduction, and convection. Thus, he has designed many types of heating systems to make his home comfortable. All these heating systems use the three natural methods of heat transfer. Pipes and ducts are used to distribute heated air, water, or steam to the various rooms of the house where heat is needed.

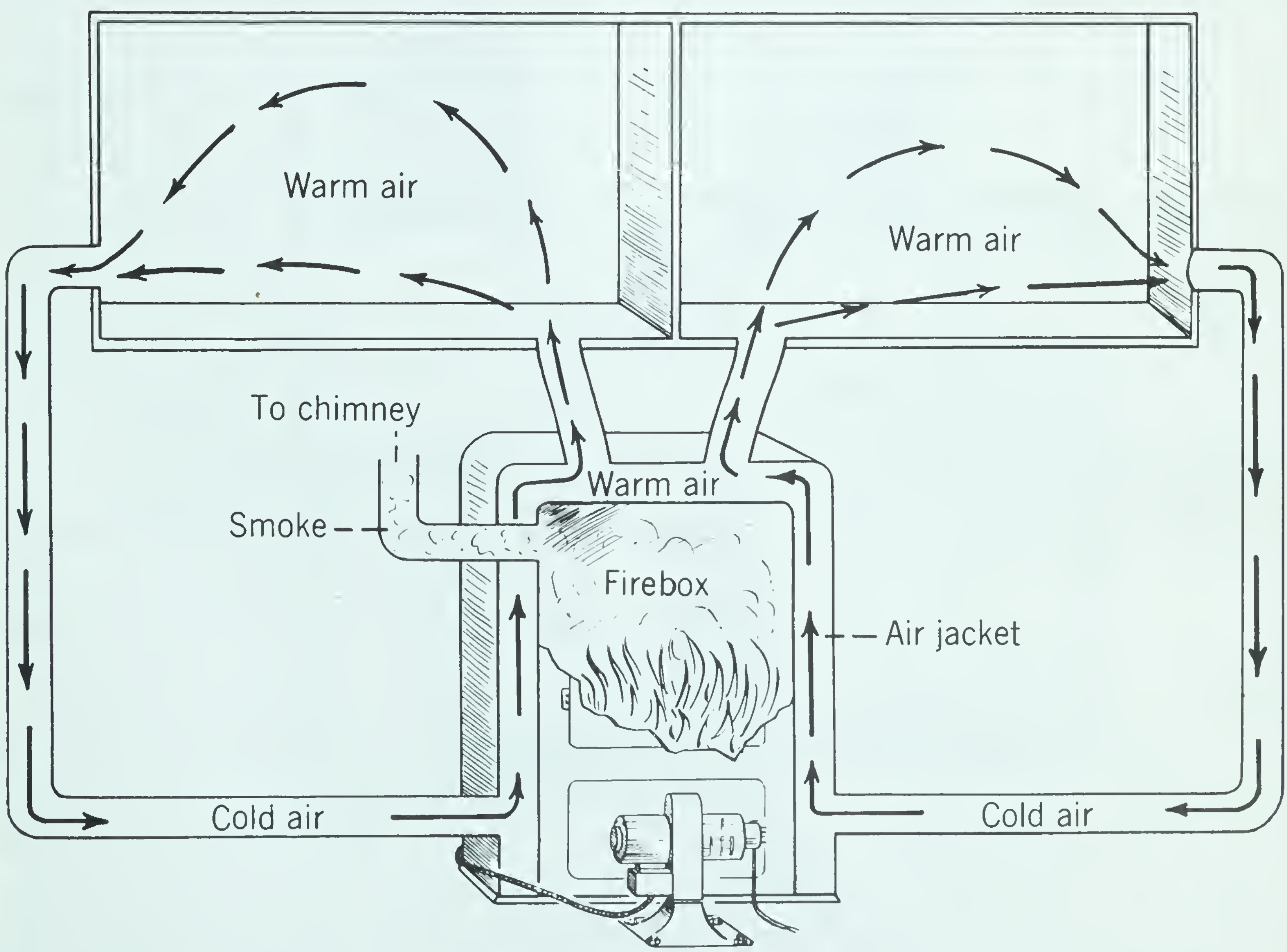


Fig. 4-18. Heat is distributed from a duct-type hot-air furnace to the rooms of a building by the process of convection. How does this differ from the pipeless type?

The hot-air furnace transfers heated air by convection. The air enters the jacket which surrounds the firebox (see Fig. 4-18). In the jacket it is heated and pushed up by the cold air which is continually entering the jacket at the bottom. The warm air rises to the rooms of the house, is cooled, and then starts moving downward. In the process, the warm air gives up some of its heat to the rooms, and returns as cool air to be reheated. So this cycle is repeated and the rooms are kept warm.

In some hot-air furnaces, air is admitted from the outside to help keep the air fresh. Usually there is enough air coming in through doors, windows, and walls of the room to supply all the fresh air you need.

The firebox of a hot-air furnace is connected with the chimney by pipes, and all the products of combustion

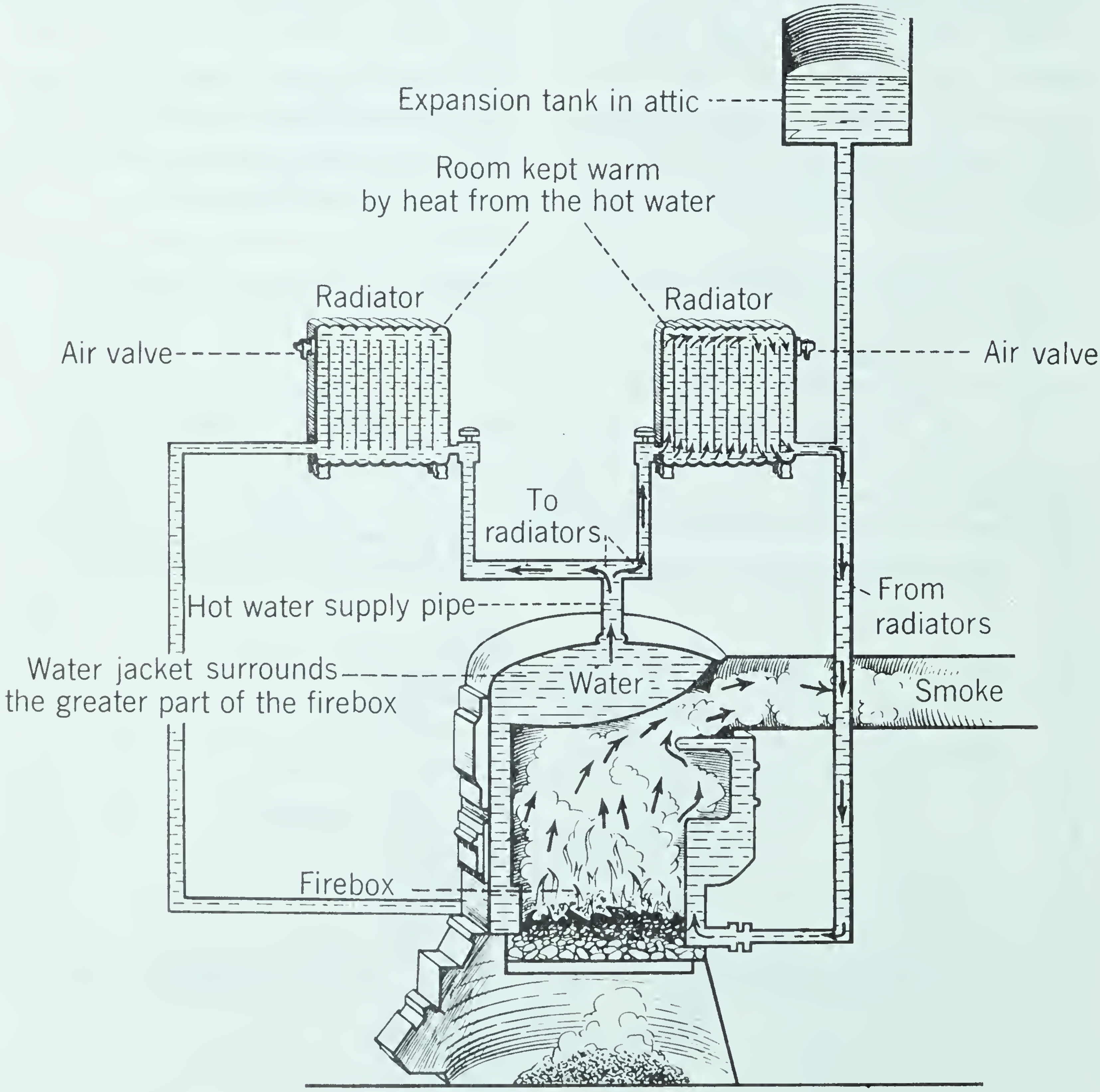


Fig. 4-19. In the hot-water heating system, heat is distributed from the boiler to the radiators, and circulated through the rooms by convection.

then pass upward through the chimney.

The heat passes through the walls of the firebox by conduction. The air surrounding the firebox is heated by radiation, convection, and conduction. In the type of hot-air system shown in Fig. 4-17, the heated air rises directly through a large register above the furnace. It is distributed to all parts of the house by convection currents. Cool air returns through the outer part of the register for reheating. In the type of hot-air furnace shown in Fig. 4-18, the heated air circulates through the pipes and rooms by convection. It returns by other pipes to the air jacket for reheating.

The hot-water heating system transfers heat by convection. In this type of system, the hot water circulates by convection through pipes and radiators. A water jacket surrounds the firebox. The heat passes through the firebox to the water jacket by conduction. The water in the furnace is also heated by radiation, conduction, and convection. The heated water expands. It is pushed up into the pipes and radiators by the colder water entering the furnace. The hot water in the radiators gives its heat to the rooms by radiation and conduction. The heated air then circulates around the rooms by convection. (See Fig. 4-19.)

Radiators must have air valves for the escape of air when they are being filled and for the entrance of air when they are being emptied. They could not be filled with water unless air were allowed to escape. An expansion tank in the attic or basement is used in hot-water heating systems to provide for the expansion of water when it is heated.

The steam-heating system transfers heat by convection, conduction, and radiation. This type of system is shown in Fig. 4-20. The boiler is only partially filled with water so some space is provided for the steam as it forms. As the amount of steam increases, the pressure increases. This increased pressure forces the steam through the pipes to the radiators.

In radiators, steam condenses and the heat previously used to turn water into steam is now set free. The water returns to the boiler to be reheated and changed to steam again. You will find several variations of this system used today, but they are all based on the same idea.

PUPIL ACTIVITY

Heat some water to boiling in a teakettle or tin pan. Hang a thermometer in the kettle or pan so that the bulb is in the water. Boil the water from 15 to 20 minutes or until some of it has boiled away as steam. Does the temperature vary as the water changes to steam? What becomes of all the heat added since the water began to boil? What is always opposing the escape of the steam from the kettle or pan?

Steam usually enters a radiator at a temperature above the normal boiling point of water. When the steam condenses to water in the radiator, it gives up the heat which was used to change it to steam in the boiler. Heat from the radiator warms the surrounding air by radiation, and the heat is then distributed to the room by con-

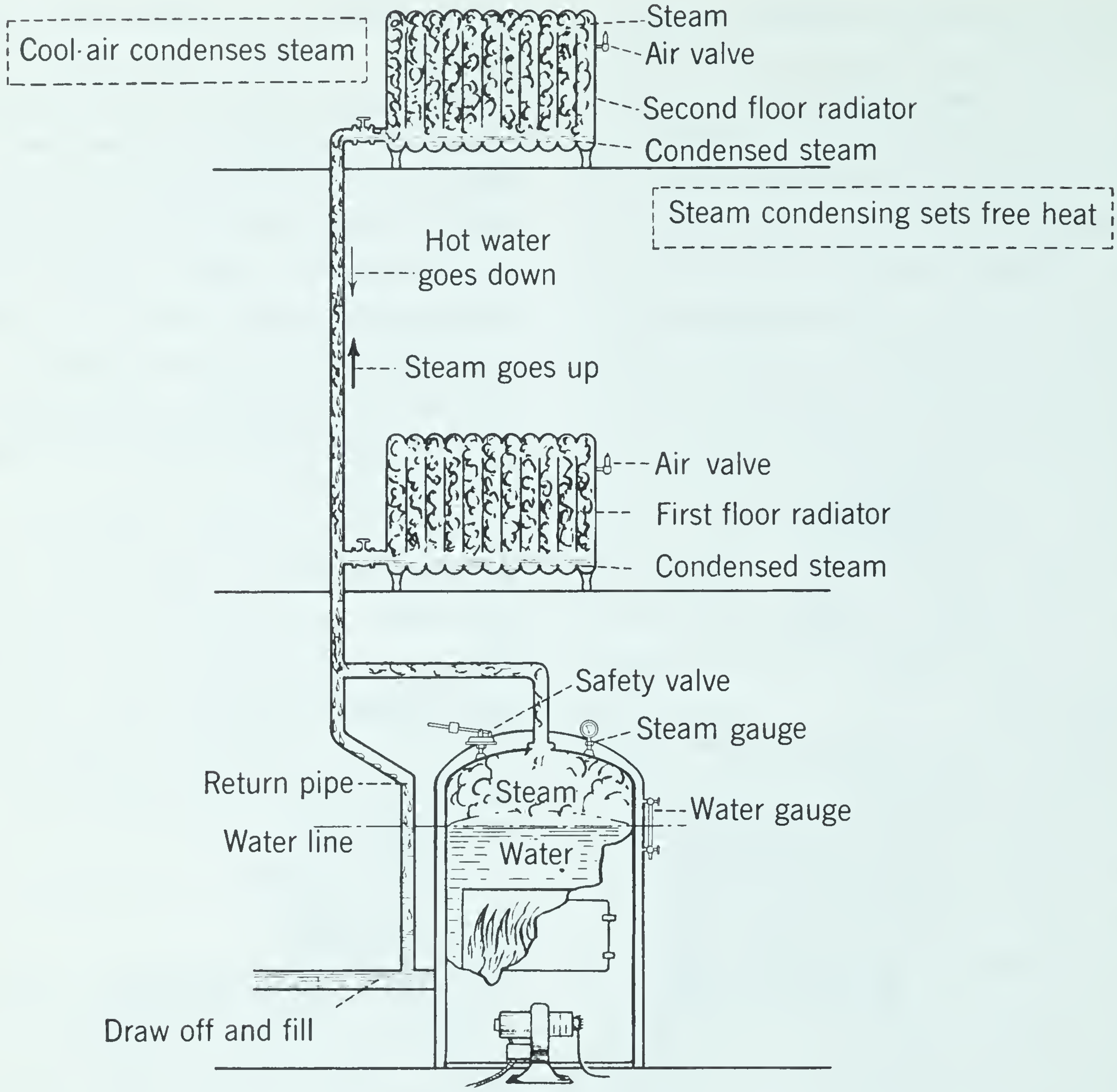


Fig. 4-20. In the steam-heating system, the steam formed in the boiler condenses to water in the radiator and sets heat free by radiation. The heat circulates throughout the rooms by convection.

vection. Thus all parts of the room are heated almost equally.

Each heating system has advantages and disadvantages. The hot-air system is cheaper to install than either steam or hot water. It is simple to operate and heats the house quickly. It also helps ventilation by bringing fresh air into the rooms. Its chief disadvantage is that dust and gases can enter with the air, although modern filters now remove much of the dust.

Although a hot-water system is expensive to install, it usually uses less fuel. It also keeps a house at a more even temperature. But it contributes nothing to the ventilation of rooms; and a leak in the system is expensive to repair.

Steam is more economical to install than hot water. Heat can be transferred greater distances with steam than with hot air or hot water. Sometimes it is carried for many miles through underground pipes. Steam heat is widely used in homes.

Many homes are today heated by gas. Oil and gas leave no smoke, ashes, or dust. The burners are easily controlled by a thermostat located in some convenient place. Oil burners are equipped with an electric motor which forces a mixture of oil and air through a nozzle. The fuel is then ignited by a flame or electric spark.

REVIEW QUESTIONS

1. Name three methods by which heat may be distributed. **2.** Give an example of each method. **3.** Name three good conductors of heat; three poor conductors. **4.** Compare the hot-air, hot-water, and steam heating systems. How does each system distribute heat? **5.** What are the advantages and disadvantages of each type of heating system? **6.** How is oil burned in a furnace?

E How can losses of heat be reduced?

A good mixture of air and fuel reduces heat losses. Whenever you see smoke coming out of a chimney, you may be sure that fuel is being wasted. Black smoke is carbon which is not being burned.

The reason for the unburned carbon is the lack of enough air to supply the oxygen. To burn fuel completely there must be enough oxygen. Otherwise, some of the vapors given off when a fuel is heated escape without being burned. Scientists have figured that it takes from 75 to 100 cubic feet

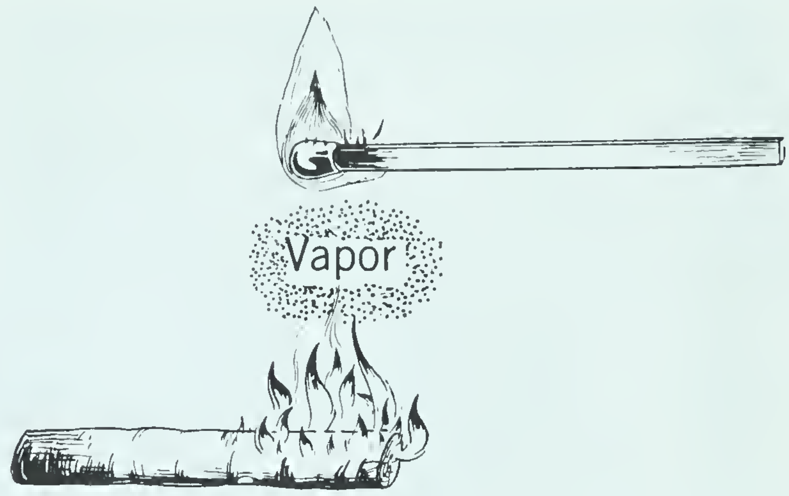


Fig. 4-21. Combustible vapors may escape from a fire without being burned.

of air to burn one pound of coal in the average furnace.

DEMONSTRATION

(A) Hold one end of a dry stick of pine wood in a fire until it burns with a large yellow flame. Blow out the flame. Hold a burning match in the smoke. Repeat several times. Results? Of what does the yellow flame largely consist? What is deposited when you hold a cool object in a yellow flame? Why does holding a burning match in the smoke help to cause it to disappear?

(B) Relight the stick and thrust the blazing end into a milk bottle. Result? Why does the flame go out? Why does the stick still smoke? Why does a fire in a coal stove or furnace smoke: (a) when you close the dampers too tightly? (b) when the range is cold? (c) when you put fuel on the fire? (d) when you try to burn green or damp wood? What is the soot in chimneys? Why do chimneys sometimes "burn out"? Why should soot and ashes be regularly removed? How can fuel be wasted? How can fuel waste be partially prevented? How can you produce a smoky flame with a Bunsen burner?

To prevent waste, the fuel must be properly mixed with air. If a furnace

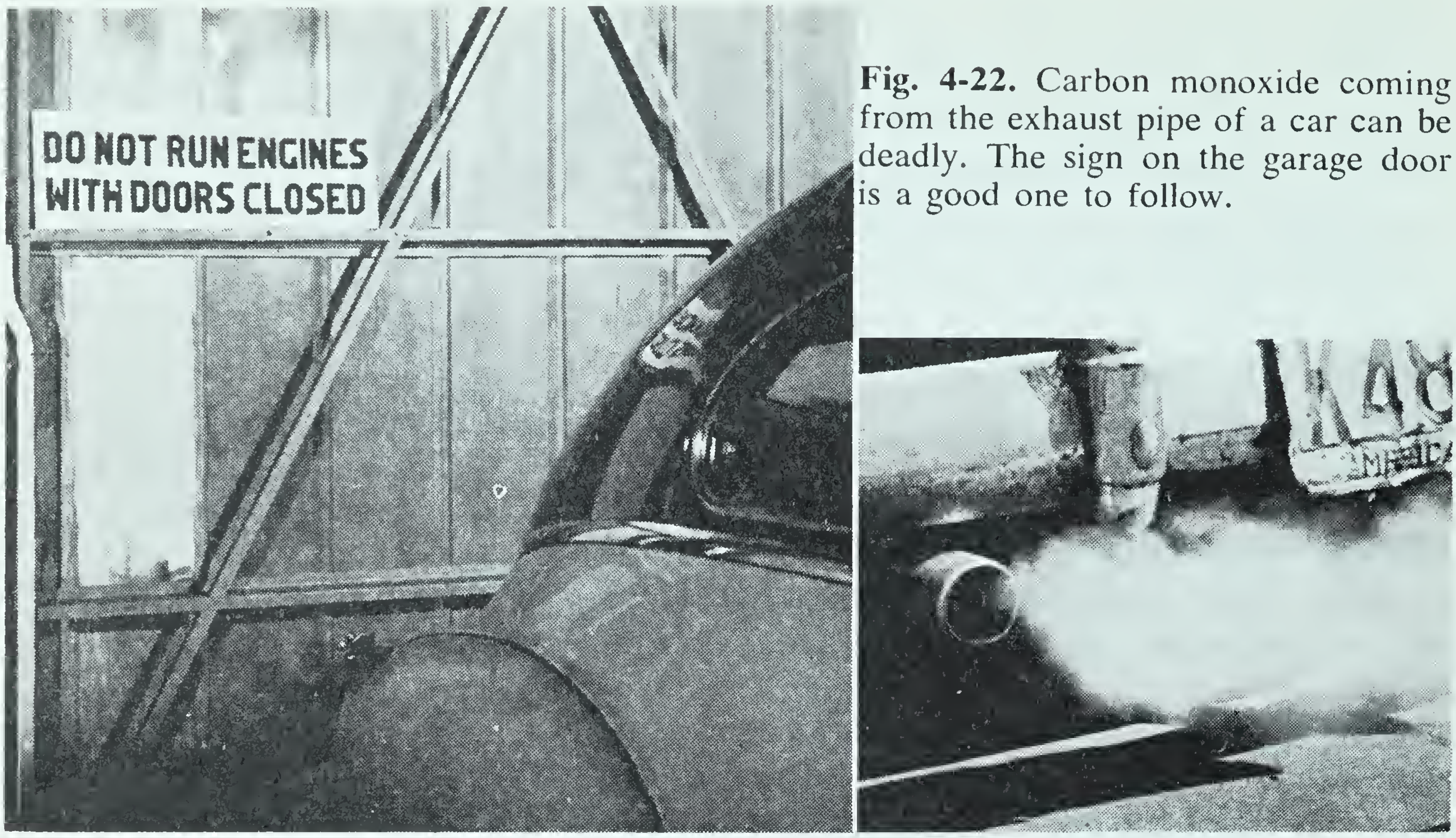


Fig. 4-22. Carbon monoxide coming from the exhaust pipe of a car can be deadly. The sign on the garage door is a good one to follow.

or burner using gas or oil is not mixing the fuel properly with air, you should ask a serviceman from the fuel company to fix it.

Carbon monoxide may result from a poor mixture of air and fuel. Observe Fig. 4-23 and see how carbon dioxide and carbon monoxide are formed by burning coal in a stove.

When carbon unites with oxygen in a stove, carbon dioxide forms in the lower part of the fuel chamber. There is enough oxygen and combustion is completed. As the carbon dioxide passes up through the hot coal, it may be changed to carbon monoxide.

Carbon monoxide forms when there is not enough oxygen to burn fuel completely. Heated carbon can take oxygen away from some other materials. This is exactly what happens when the carbon dioxide gas passes

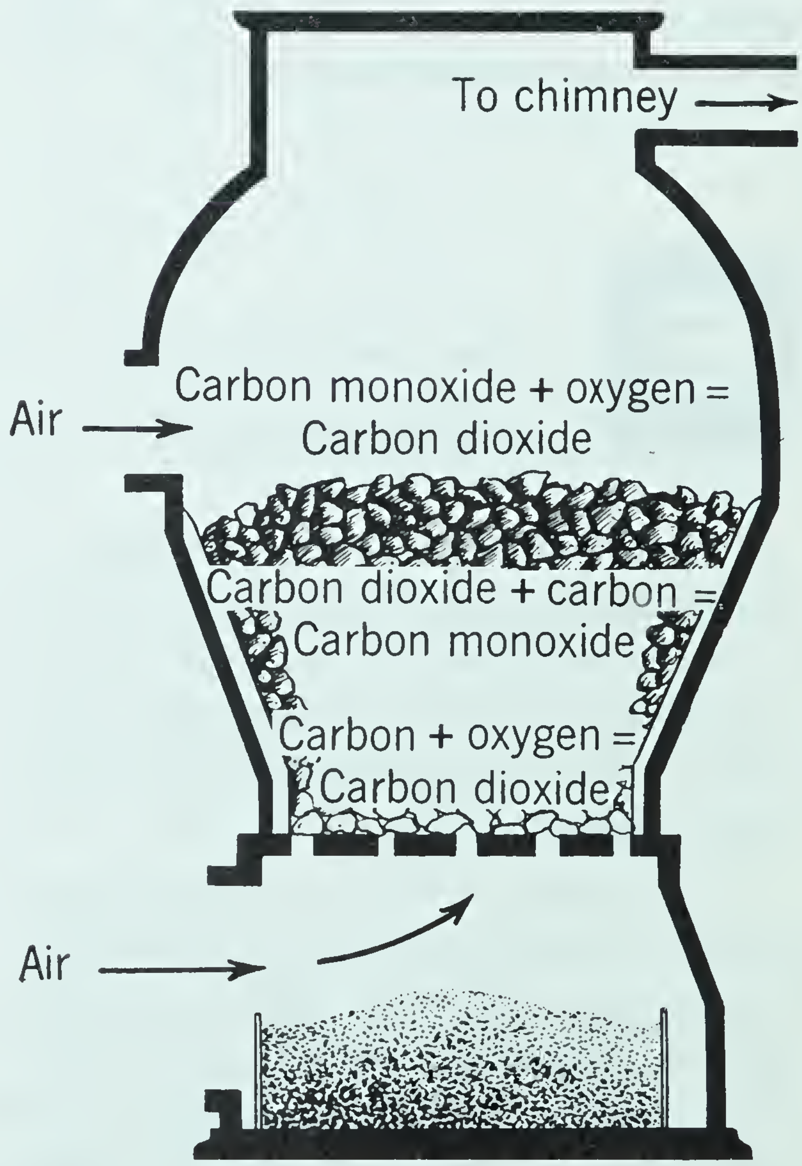


Fig. 4-23. Carbon monoxide forms when the supply of oxygen is insufficient to burn the fuel completely.

through red-hot coal. The carbon monoxide can escape into the room without being burned if there is a poor draft through the fire, or if the check damper is too tightly closed. Some carbon monoxide is produced in all burning fuels.

Carbon monoxide is a colorless, odorless gas and is a deadly poison. If you breathe small quantities of it for 15 minutes, it will cause serious results, possibly death. It is very dangerous because you cannot see it or smell it. It is never safe to stay in a closed garage when the engine of a car is running, because the gas engine of the car does not burn its fuel completely. Some carbon monoxide gas escapes through the exhaust. Gas heaters and stoves in houses should be well regulated to prevent the formation of carbon monoxide.

Heat loss is reduced by using good insulators. Some heat always escapes through the furnace and pipe walls into the basement. More heat is wasted when it escapes into the outer air through the walls of the house. How can we reduce such waste?

PUPIL ACTIVITY

Make a pad by stuffing a small cloth bag with small pieces of paper, sawdust, wool, cotton, and straw, each in turn. Using the pad, can you lift hot articles with comfort? What is your conclusion as to the conductivity of these substances? Remember that these and similar substances such as hair, fur, asbestos, and feathers hold much air, and air is a very poor conductor of heat.

If possible, get a piece of asbestos. Does heat pass readily through it? Put it in a flame? Will it burn? What is best for covering the furnace or for covering the heater pipes? What substances are good heat insulators?

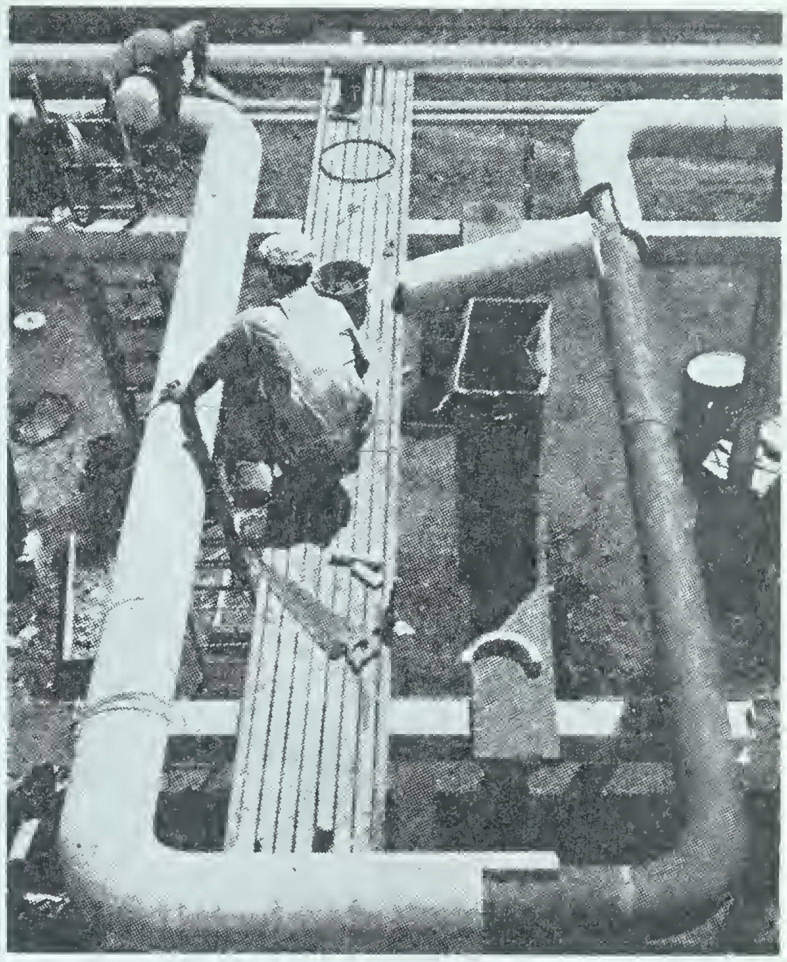


Fig. 4-24. These workmen are insulating pipes in a large industrial plant.

The outer surface of a furnace or heater should be covered with a layer of some material that is a poor conductor of heat, such as asbestos. Materials like asbestos and glass wool which do not conduct heat readily are called *insulators*. These are often used in the walls and roofs of houses to prevent loss of heat in the winter. In the summer they help to prevent the house from becoming heated by the warm air outside. Air spaces, paper, and wood are used as insulators in buildings.

Storm windows help prevent heat loss because the air trapped between them and the windows is a good insulator. Some large modern windows are

Fig. 4-25. Insulation between the rafters above the upper ceiling helps prevent the loss of heat.

made of a double layer of glass with an air space between them. This makes it possible to give a house more window area without a corresponding loss of heat.

Heat loss is reduced by using good reflectors. Bright, shiny surfaces are good reflectors but poor radiators. This is why the furnace pipes are shiny tin or aluminum. This prevents radiation of heat before it gets to the room. On the other hand, surfaces that are poor reflectors are good radiators. This is why the radiators should be dull-colored. A dull finish on a radiator gives out heat into the room better than a bright shiny one.

DEMONSTRATION

Get two cans of the same size and remove the labels. Blacken one by holding it in the smoky flame of a candle or Bunsen burner. Now heat water in a larger container until it boils. What is its temperature? Pour equal amounts of the hot water into each of the two cans. Take the temperature of the water in each can at two minute intervals. Result? Conclusion?

Will a black or a shiny radiator give out heat better? Can you boil water quicker in a bright aluminum kettle or in a black kettle? Should the bottom of teakettles be kept shiny? Explain.

The Thermos bottle reduces heat loss. In understanding how this useful bottle works, we have to see how it

controls conduction, convection, and radiation.

The bottle is made of two layers of glass. Air is pumped out from the space between the two layers, resulting in a nearly perfect vacuum. Such a vacuum stops heat loss by conduction and convection. The inside surface of the outer layer, and the outside surface of the inner layer are coated with a silvery substance. This reduces radiation. See Fig. 4-26.

Thus all three ways of transferring heat are partially prevented and liquids will stay either hot or cold in the bottle for several hours. If they are hot, the heat cannot escape; and if they are cold, the heat cannot get in.

Refrigerators are built to prevent heat from entering. Before the days of electric refrigerators, food would keep for several days in an icebox even though the piece of ice gradually melted. This was because iceboxes were built with good insulation. Electric refrigerators today use the same idea. Their walls contain several layers of good nonconducting materials like wood, air, cork, and fiberglass.

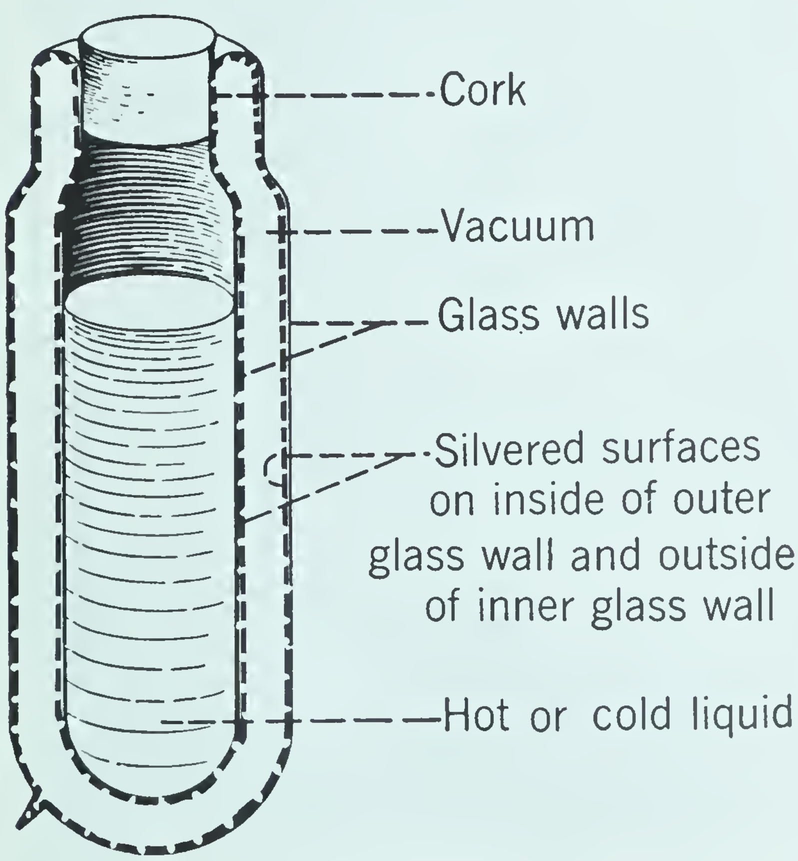


Fig. 4-26. The Thermos bottle is designed to prevent heat transfer by conduction, convection, and radiation.

Saving heat is largely a matter of knowing how to reduce its loss by conduction, convection, and radiation.

REVIEW QUESTIONS

1. In what ways can fuel be wasted by a stove or heater? **2.** What is smoke? **3.** Under what conditions is smoke formed? **4.** How may the walls of a house be constructed to prevent loss of heat? **5.** What type of material makes a good radiator? **6.** Why does a Thermos bottle keep hot things hot and cold things cold?

F How is a modern house air-conditioned?

All houses need a good circulation of air. In building houses the contractor must be sure that the air can be kept circulating through the rooms. Why is fresh air necessary?

PUPIL ACTIVITY

Breathe on the bulb of a thermometer. Result? Breathe on a cold window pane. Result? Blow your breath through a tube into some limewater. Result? (If the limewater turns cloudy, it indicates the presence of carbon dioxide.) Breathe into a clean fruit jar or milk bottle and fasten the cover on. Set it aside in a warm room for a day or so.

A bad odor indicates the presence of decaying wastes that were in the breath. Odors are present in sweaty gym suits since similar waste passes out through the skin when we perspire.

A room filled with people soon becomes uncomfortable unless it is properly ventilated. The discomfort is caused largely by an increase in the amount of water vapor and to some extent by a decrease in the supply of oxygen.

The content of water vapor (humidity) is greater in crowded rooms because of perspiration and moisture in the exhaled air.

To keep people comfortable in crowded rooms, we must have a regular movement of fresh air.

DEMONSTRATION

(A) Make a ventilating box with a glass front. Put a lighted candle under one of the openings and close the glass front tightly. Put a smoking piece of wood or a smoking stick over the other (cool) opening. Result? In which direction does the air in the box move? Which column of air is heavier? Then why does the light air rise? What are the sources of heat in your classroom? (Remember that your normal body temperature is 98.6° F.)

In which direction does heated air move? In which direction will the cooler air flow? What are convection currents?

(B) Open the door leading from a warm room to a cold one. Hold a smoking match near the bottom of the doorway. Result? Remember the effect of heat on air. Open the window at the top and bottom. Test for currents of air at both openings. Results? Explain. If the temperature of the air inside the room and outside the room is the same, and you find no air currents, explain. Is there a current of air in your classroom? How is it created? Make a sketch to show the main convection currents. How does fresh air enter the room?

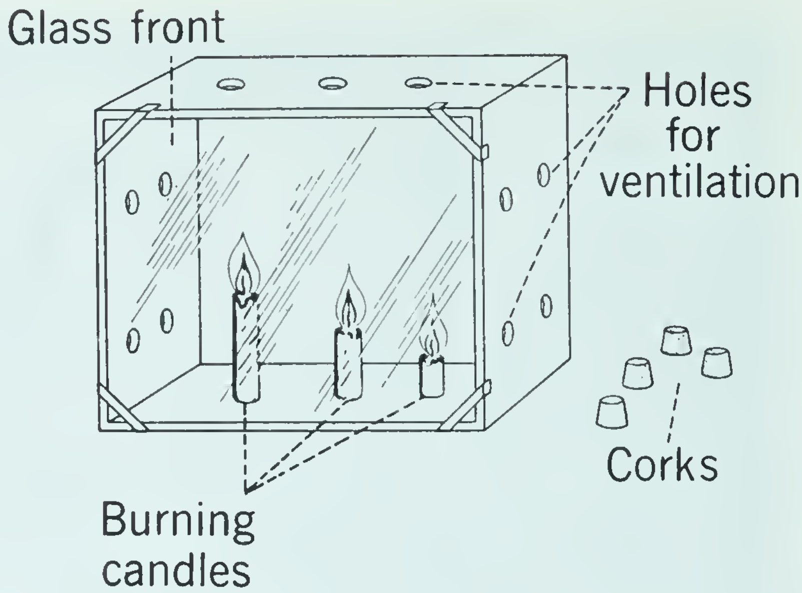


Fig. 4-27. When the air in this ventilating box is heated, it circulates and moves toward the top.

Air will circulate in a house by convection. But you need some kind of forced ventilation if the building is large. In a house, enough air usually comes in around the doors and windows and through the walls to supply all the fresh air necessary.

What is an air-conditioning system? A complete air-conditioning system is a ventilating process which does four things: (1) heats or cools the air; (2) filters it to remove dust; (3) keeps the right amount of moisture in it; and (4) keeps the air moving.

In one type of fan-ventilating system, air is removed from the room, forced through a filter to remove dust, and returned to the room. In another type, air is also forced through a fine spray of water to remove dust. This method has the advantage of adding moisture to the air at the same time dust is removed.

What is relative humidity? The capacity of air to hold moisture increases with the temperature. Warm air can hold *more* water vapor than cold air.

We complain about humidity of the air when a day is especially moist. *Humidity* (hew-*mid*-ih-tee) means moisture or water vapor in the air. But we should say more than just "humidity" in speaking of weather. We should say the *relative humidity*. ***Relative humidity*** is the amount of water vapor present in air compared with the amount the air can hold at that temperature, expressed in per cent. People are most comfortable when the relative humidity is between 45%-55% just as they are most comfortable when the room temperature is between 68°-70° F.

Fig. 4-28. These scientists find working in an air-conditioned room more comfortable. The air-conditioner is at the left.

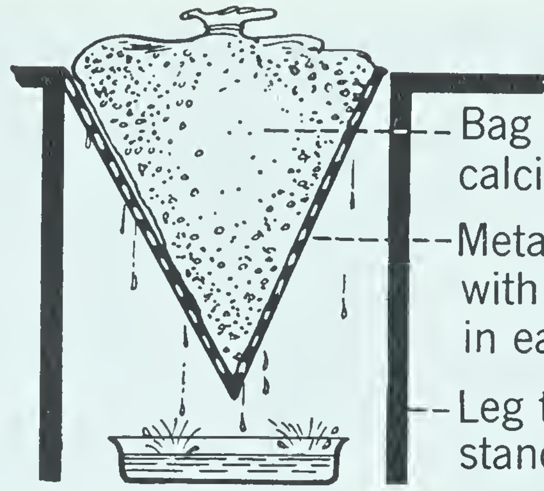


Fig. 4-29. By using a drying agent in summer, such as calcium chloride, you can decrease the relative humidity.

Humidity in a house can be partially controlled. As a rule, our houses are too dry in winter and too damp in summer. When too dry, the rate of evaporation from the skin is increased, and the skin may become parched. Rapid evaporation also cools the body and a higher room temperature is needed to be comfortable. For this reason you may feel as warm in a room with high humidity at 66° F. as in a room with low humidity at 72° F.

In winter, when outside cold air with a relative humidity of 50% or more is heated, its relative humidity may drop to as little as 10%. If cold air is heated, its capacity for holding moisture is increased and its relative humidity is lowered.

In cold weather we should add water vapor to the air. In houses without air-conditioning this is done by evaporation of water from containers in the furnace or on radiators. Wet cloths put on radiators also help. Moisture-conditioning units are now available for adding water vapor to the circulating air. Modern air-conditioning

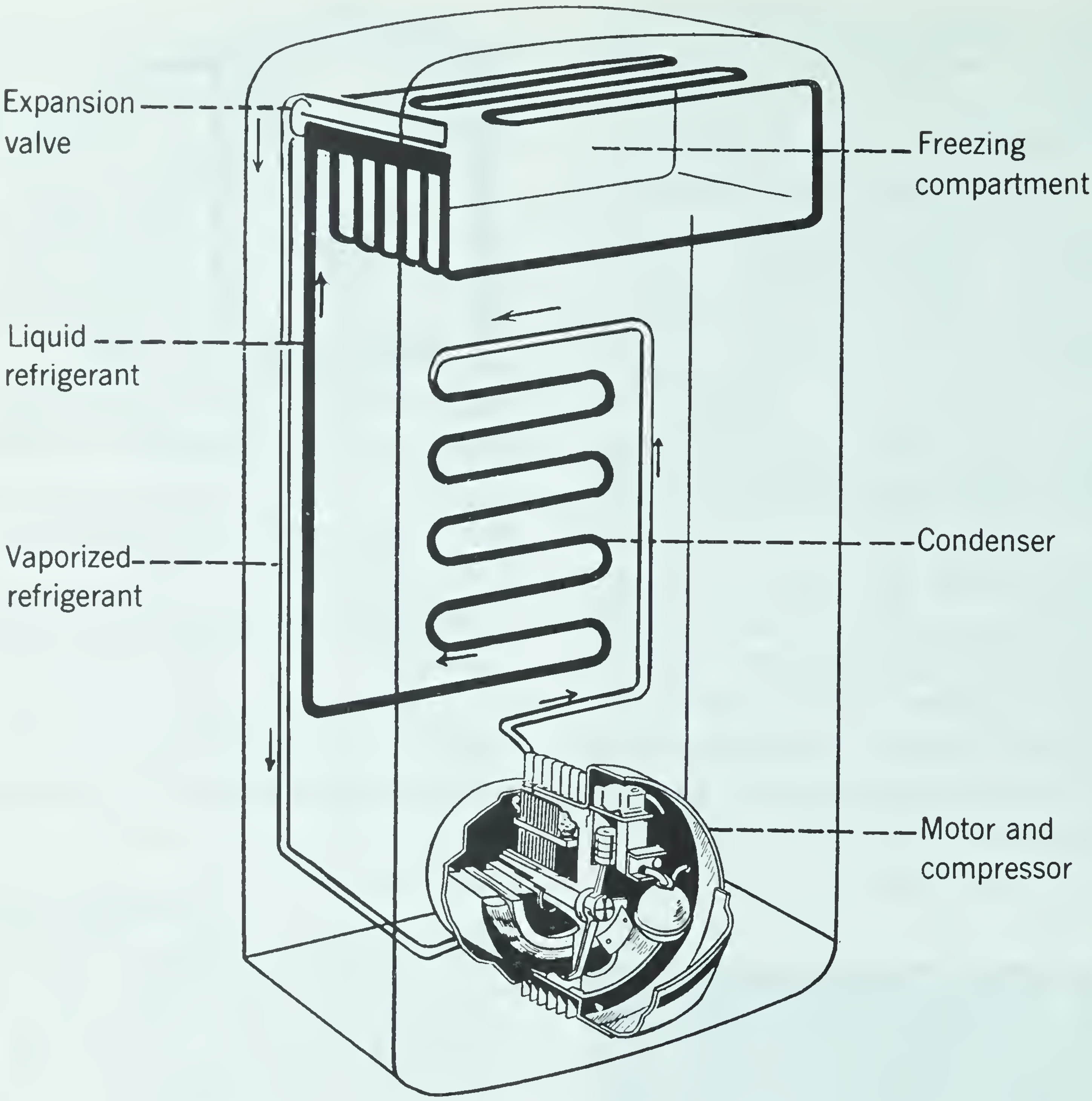


Fig. 4-30. The electric refrigerator is cooled by the evaporation of a liquid. Good insulators keep heat from entering the refrigerator.

units, of course, automatically moisten the air when the relative humidity falls too low.

In summer, without air-conditioning, there is not much you can do to decrease the moisture in the air. You can, however, hang bags containing a drying agent (calcium chloride is good) around the house. This compound absorbs moisture in the air, thus leaving the air drier. Be sure to put a pan under the bag of calcium chloride as shown in Fig. 4-29 and close the doors and windows. You can also buy electrical dehumidifiers. These remove moisture from the air without changing its temperature.

Heat is absorbed when a liquid evaporates. This fact is used in air-conditioning systems and in electric refrigerators.

DEMONSTRATION

Wrap two or three layers of cheesecloth around the bulb of a thermometer and fasten with a string. Dip the cloth in water at room temperature and then move the thermometer back and forth

Fig. 4-31. This workman is plastering over the pipes which will distribute heat by radiation. Compare the use of these coils with Fig. 4-30.

through the air rapidly. How is the thermometer affected? What caused the change?

Put a small quantity of ether in a large watch glass. Blow air across the surface of the ether. Take the temperature of the ether once a minute for three minutes. Explain the result. (CAUTION: *do not allow a flame of any kind in the room in which ether is used.*)

In the electric refrigerator, a liquid is evaporated in the cooling unit. This liquid absorbs heat from the box and cools it. The cooling unit of an air-conditioning system works in the same way. Evaporation of a liquid is the most satisfactory way of getting low temperatures. At present, several good liquids for cooling are available. They evaporate at a low temperature and absorb a large quantity of heat in doing so. Warm air is forced over the cooling unit and is cooled to the temperature desired.

REVIEW QUESTIONS

1. What four things should you do in the proper conditioning of air? **2.** How is air made to circulate? **3.** When is air impure for breathing purposes? **4.** How is water vapor removed from air? How is water vapor added to air? **5.** How can air be cooled and circulated to keep our houses more comfortable in summer? **6.** What causes the temperature of a liquid to become lower as it evaporates? **7.** Why is the condensing unit placed outside the cooling part of the refrigerator? **8.** What properties are required of the liquids used in the cooling system of an automatic refrigerator? **9.** What range of relative humidity is most comfortable for humans?

QUESTIONS FOR REVIEW AND DISCUSSION

1. Compare the methods used to produce heat now with the methods used in ancient times.
2. What is the most important source of the earth's heat energy?
3. In what three ways is heat produced?
4. What is the effect of a change in temperature on the volume of liquids, solids, and gases?
5. Why do moving parts of machines sometimes "freeze" tight?
6. What is the meaning of temperature? How is it measured?
7. What two units are used to measure quantities of heat? What is the definition of each unit?
8. How is the air supply of furnaces regulated?
9. How are air and gas mixed in a Bunsen burner? In a gas stove? In an oil burner?
10. In what three ways can heat be distributed?
11. How is the loss of heat prevented in house walls? In a refrigerator? In a Thermos bottle? Which uses the best method to prevent loss of heat?
12. Compare a hot-air furnace, a hot-water heating system, and a steam-heating system for: (a) methods used to distribute heat; (b) ventilation; (c) cost of installation; (d) size of houses for which they are suitable; (e) uniformity of heating.
13. What are three ways in which fuel can be wasted in a furnace or stove?
14. Under what conditions is carbon monoxide gas formed during combustion?
15. What is the meaning of ventilation? When is a house well-ventilated?
16. What makes the air in a house impure?
17. What is the most comfortable temperature and humidity for a classroom? For a gymnasium?
18. What are the advantages of oil and gas over coal and wood as fuels? What are the disadvantages?
19. How is the humidity of the air in a room increased in cold weather and decreased in warm weather?
20. What are the different methods of cooling air-conditioned houses in summer?
21. In what different ways can the efficiency of your house-heating plant be improved?
22. What are the materials used for insulation against the loss of heat in a house?
23. What are the objections to the use of cold water in some cities for cooling houses?

24. Give a summary of the progress made in heating and ventilating buildings from ancient times to the present. What new ideas or principles have been developed? What improvements remain to be made? How does the cost of new houses compare with the cost of houses in ancient times?

25. In what part of a refrigerator is a liquid evaporated? In what part is the vapor changed to a liquid? What energy change occurs in each case?

26. What properties does calcium chloride have that makes it a good chemical to keep the relative humidity low, and to keep the dust from rising?

27. How is the capacity of air for holding water affected by (a) heating the air, (b) cooling the air?

28. Under what conditions is it possible to have a relative humidity of 100% on a day when the temperature is 90° F. and also on a day when the temperature is below freezing?

29. What is meant when it is said a refrigerator is defrosted? Why is it necessary to have some system of defrosting?

30. Why are vegetables kept in covered containers when placed in refrigerators?

31. In each of the following energy changes is heat energy absorbed or set free? What practical use is made of some of these changes?

a. Ice melts.
b. Water evaporates.
c. Water freezes.
d. Water is boiled to make steam.
e. Steam condenses.

SPECIAL REPORTS AND PROBLEMS

1. Make a model of a hot-water heating system.

2. Make a model of a steam-heating system.

3. How is your school building ventilated?

4. Demonstrate how a Thermos bottle prevents loss of heat.

5. Make a fireless cooker and describe its efficiency.

6. Measure the humidity in your house and in the schoolroom.

7. The history of the development of the stove.

8. How my house is heated and ventilated.

9. Air-conditioning in a modern house.

10. How they cook at a real New England clambake.

11. Commercial uses of air-conditioning.

TESTING THE PURPOSES OF THIS UNIT

1. Give the meaning of the following words or terms: temperature, small calorie, large Calorie, Btu, conduction, convection, radiation, insulator, ventilation,

humidity, relative humidity, Fahrenheit scale, Centigrade scale, freezing point, boiling point.

2. What is your attitude toward the following statements?
   a. Night air is bad for breathing.
   b. The old-fashioned stoves are better than the new stoves.
   c. A modern house does not need a ventilating system.
   d. Air-conditioning in summer is unhealthful.

3. In many cities fuels are sold on the basis of the number of heat units a pound or ton will produce when burned. The price paid is determined on the basis of the heat units in a ton. Why is this a more satisfactory plan than paying so much per ton without having the fuel tested for its heat value?

4. If you were going to install a heating system in your house, how would you proceed to do it if you followed the scientific method? What problems would you consider? How would you solve each problem?

5. According to the kinetic theory, heat is due to molecular motion. Explain by the use of this theory why the earth's surface is heated by the sun's rays and why water does not heat as rapidly as land.

6. Inspect the heating system in your house. Which of the three main types is it? Make a rough drawing showing the main parts. Label the diagram and be able to discuss the uses of its parts.

7. Three general methods are used in getting heat from the sun for use in the home and in industry. In each of the following methods, explain how the heat energy is used or may be used:
   a. Large curved reflectors are used to focus the sun's rays on a much smaller area.
   b. The sun's heat is used in the daytime to change a chemical from a solid to a liquid. The chemical is put in black cans or drums.
   c. The sun's heat is absorbed by black cloth or some other black material. In heating houses, the black material is placed under a glass roof.

8. What material is used as the refrigerant in your electric refrigerator at home?

9. Give examples of how geographic location influences the type or kind of fuel used for heating the homes.

10. Why is the temperature of the air in the basement of your home usually cooler than that of the upstairs rooms in the summertime?

11. Some times in the summer when you drive your car from the garage a thin film of moisture appears on the windows of the car. What causes this? Also, the floor of the garage will become moist. Explain the cause of this moisture.

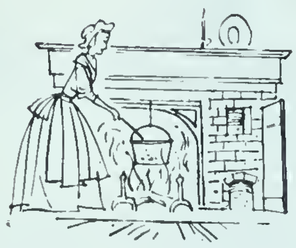
12. Name some of the types of insulating materials used to prevent heat from coming through the ceiling of your home.

13. What is the purpose of the wide overhanging eaves found on many of the modern ranch-type homes?

14. Why are greenhouses able to raise tomatoes and other vegetables in the wintertime?

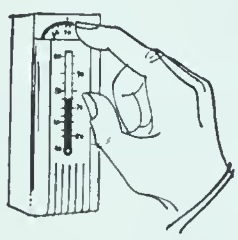
The old

MAN HAS MADE PROGRESS IN PROTECTING HIMSELF FROM the rapid changes in temperature with which he may come in contact. In ancient times, he made an open fire to produce heat, and he used tents, caves in the ground, or shacks to keep in the heat.



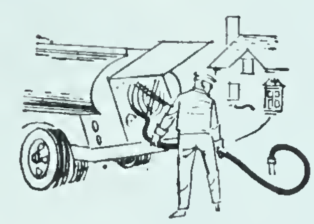
The place for the fire was moved toward the sides of these shelters, and chimneys were built. Then air and burning fuel were better mixed by means of what we now call fireplaces, and later by stoves. These inventions helped to distribute heat throughout the rooms. They also helped ventilate the rooms in which the fires burned. But there was much heat loss in the burning of fuels, and much heat escaped through the walls, doors, and windows.

The new



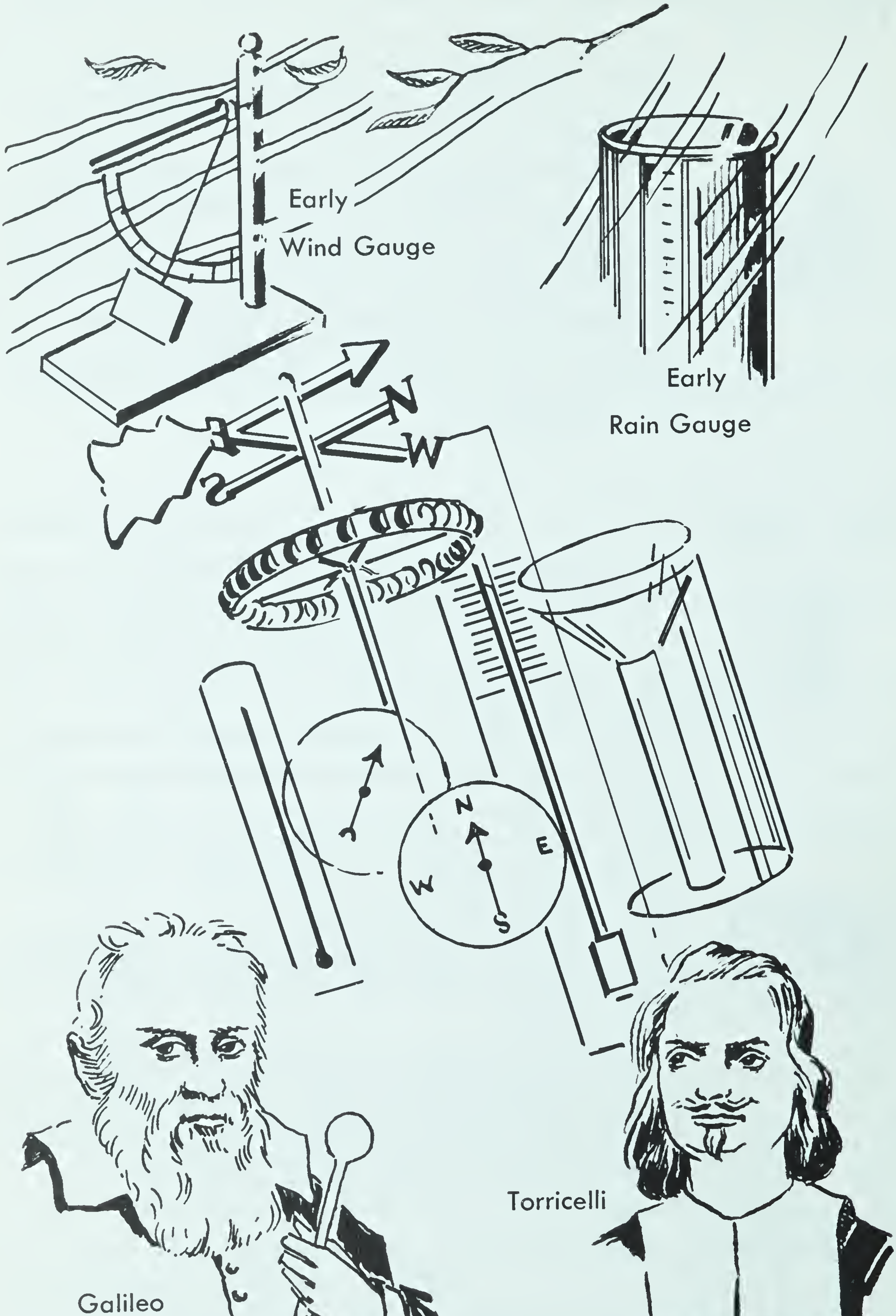
MODERN MAN HAS FOUND A WAY TO AIR-CONDITION HIS HOUSES and buildings so that he can live and work more comfortably and efficiently in the summer. He can also travel in air-conditioned trains, buses, and airplanes. Even some automobiles are now air-conditioned. He has also learned how to insulate his house in the winter.

Today our modern houses are built in new ways to prevent loss of heat. Stoves and furnaces burn fuels more efficiently and heat is distributed to all parts of the house. This distribution helps to ventilate our homes and also helps to make possible the addition of moisture. We can thus maintain a more comfortable atmosphere.



As a result of improvements due to man's progress, our houses today are much more comfortable than were the houses of our ancestors.

Experiments with solar energy indicate that it is possible to use the sun's radiant energy for many purposes. In the future we shall see homes in many parts of the country that are heated entirely or in part by solar energy.


Early
Wind Gauge
Early
Rain Gauge
N
W
N
E
W
S
Torricelli
Galileo

UNIT 5

How has man learned the causes of changes in weather and climate?

DISCOVERY AND PROGRESS

WE are all interested in weather and climate. In fact, early man was just as interested in these conditions as we are today. But he accepted them without question and did nothing to study them. The earliest record we have of any study of weather is a book *On Winds*. It was written by one of the early Greeks and tells of his studies on weather signs.

Not until the 16th Century did anyone really make accurate weather notes. At that time the Danish scientist,

Tycho (*ty*-ko) Brahe (*brah*-uh), corrected many false ideas which many people believed about the weather. Then in 1570 in Italy, Egnatio Danti (*dan*-tee) built instruments for measuring the force of the wind. Another Italian inventor, Castelli (cas-*tell*-ee), made the first rain gauge in the 17th Century. We use gauges like his today for measuring rainfall.

One of the earliest devices for measuring the amount of moisture in the air was described in the 11th Century by Cardinal Cusanus (kew-*say*-nus): "If you suspend from one side of a large balance a quantity of wool, and from the other side stones, so that they weigh equally in dry air, then you will see that when the air inclines toward dampness, the weight of the wool increases, and when the air tends to dryness, it decreases." This device has been improved over the years. We will learn more about it in this Unit.

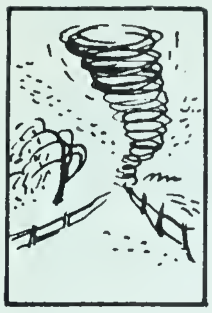
One night in 1747, Benjamin Franklin planned to study an eclipse of the moon from his Philadelphia home. His brother, living in Boston, was also going to study it. Then they would compare notes later. A heavy rainstorm appeared in Philadelphia, from the northeast—the direction of Boston. When Franklin later learned from his brother that the sky had been clear in Boston, he was surprised. He asked further about the storm, and found that it had come from the southwest. His brother wrote that the wind just above the ground came from the northeast. He found that the air was moving in a great whirl, and that the storm moved from Philadelphia to Boston, where it arrived the next day.

Cyclonic storms aid in determining weather at the present time. The study of these storms helps in understanding winds and weather. We now know that they usually move eastward across the United States. Weathermen determine how wide an area they occupy and how fast they travel.

In 1840 the first Meteorological and Magnetic Observatory was established in Canada and located in Toronto. In 1871 the Meteorological Service of Canada was organized. Its daily weather forecasts, based on scientific facts, have become essential to modern industry, agriculture and aviation. They appear daily in our newspapers and are broadcast over radio and television.

Progress is being made in long-range weather predictions. At present, predictions can be made accurately for only a few days. With more rapid transportation by airplanes it becomes necessary to make plans several days in advance. If all nations would cooperate and distribute weather reports to each other, weather forecasts might be made weeks in advance.

Artificial methods of producing rain may become more successful. If they do, man will be able to produce greater quantities of food without some of the difficulties he faces now. Farmers will produce crops on land which they now dare not use because of lack of rain. At the present, however, artificial rainmaking is not satisfactory. It needs more investigation to make it the answer to the farmer's dreams.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. Why do clothes dry better on warm days than on cold days? **2.** Why does water often collect on cold water pipes in summer? **3.** Why do ice pitchers "sweat"? **4.** Why do fogs usually collect about icebergs? **5.** What causes the winds to blow? **6.** Where does rain come from? **7.** Of what value to farmers are the reports of the Meteorological Service of Canada? **8.** How are deserts formed? **9.** Where are the places of greatest rainfall in Canada? **10.** What is the difference between weather and climate? **11.** What are the signs of approaching rain? **12.** From what direction does the wind usually blow before a storm? **13.** How does the temperature usually change after a storm? **14.** Why do eyeglasses become covered with mist when brought into a warm room from the cold outer air? **15.** What are the causes of land and sea breezes?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

condensation .... (kon-den-*say*-shun), the changing of water vapor into liquid water.

climate .... the average of weather conditions over a period of time for a particular geographical locality or area.

dew point ...... the temperature to which the air must be cooled in order to cause gaseous water vapor to condense into liquid water.

high pressure area a region of greatest atmospheric pressures.

low pressure area a region of least atmospheric pressures.

stratosphere .... (*strat*-us-feer), that part of the atmosphere extending beyond the troposphere.

troposphere ..... (*traw*-pus-feer), that part of the atmosphere extending from the surface of the earth to an average height of eight to nine miles.

A How are clouds formed?

Clouds form one of the most important elements in weather. They indicate changing weather conditions as well as giving rise to rain, snow, hail, sleet, drizzle, and thunderstorms. Therefore, it is most important that you should understand how clouds are formed.

If you watch the steam issuing from the spout of a kettle that contains boiling water, you will notice that there is a small space at the lip of the spout of the kettle where there is no steam, and that when the steam has risen to a height of a foot or more it disappears. Let us see how this simple observation may be applied to explaining how clouds are formed.

When water is heated until it boils, the liquid water turns into an invisible gas (*water vapor*) which bubbles to the surface of the water. The bubbles break and the water vapor passes into the air. When the water vapor rises from the spout of the kettle, it is cooled by contact with the cool air. The cooled water vapor is converted once again into visible liquid water (*condensation*) in the form of small droplets of water that are suspended in the air. A collection of such small, visible water droplets formed by the condensation of invisible water vapor is termed *steam*. As the steam rises into the air it evaporates or turns again into invisible water vapor.

DEMONSTRATION

Place a pyrex glass beaker of water over a flame and bring the water to the boiling point. Notice the invisible water vapor forming bubbles that rise to the surface. Now place a kettle, preferably one with a long spout, containing water, over the flame and bring the water to the boiling

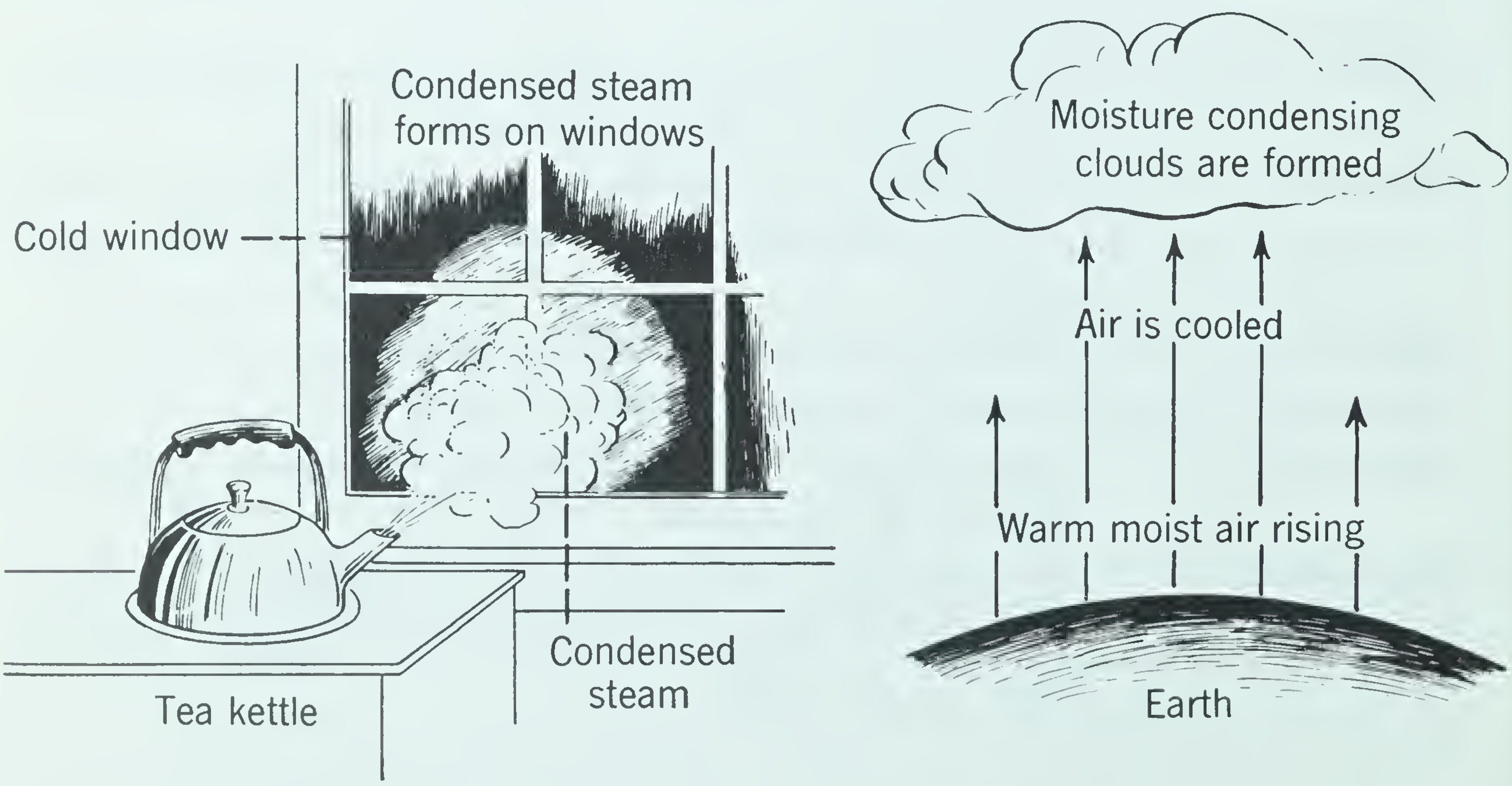


Fig. 5-1. Water vapor condenses when it is cooled to the dew point.

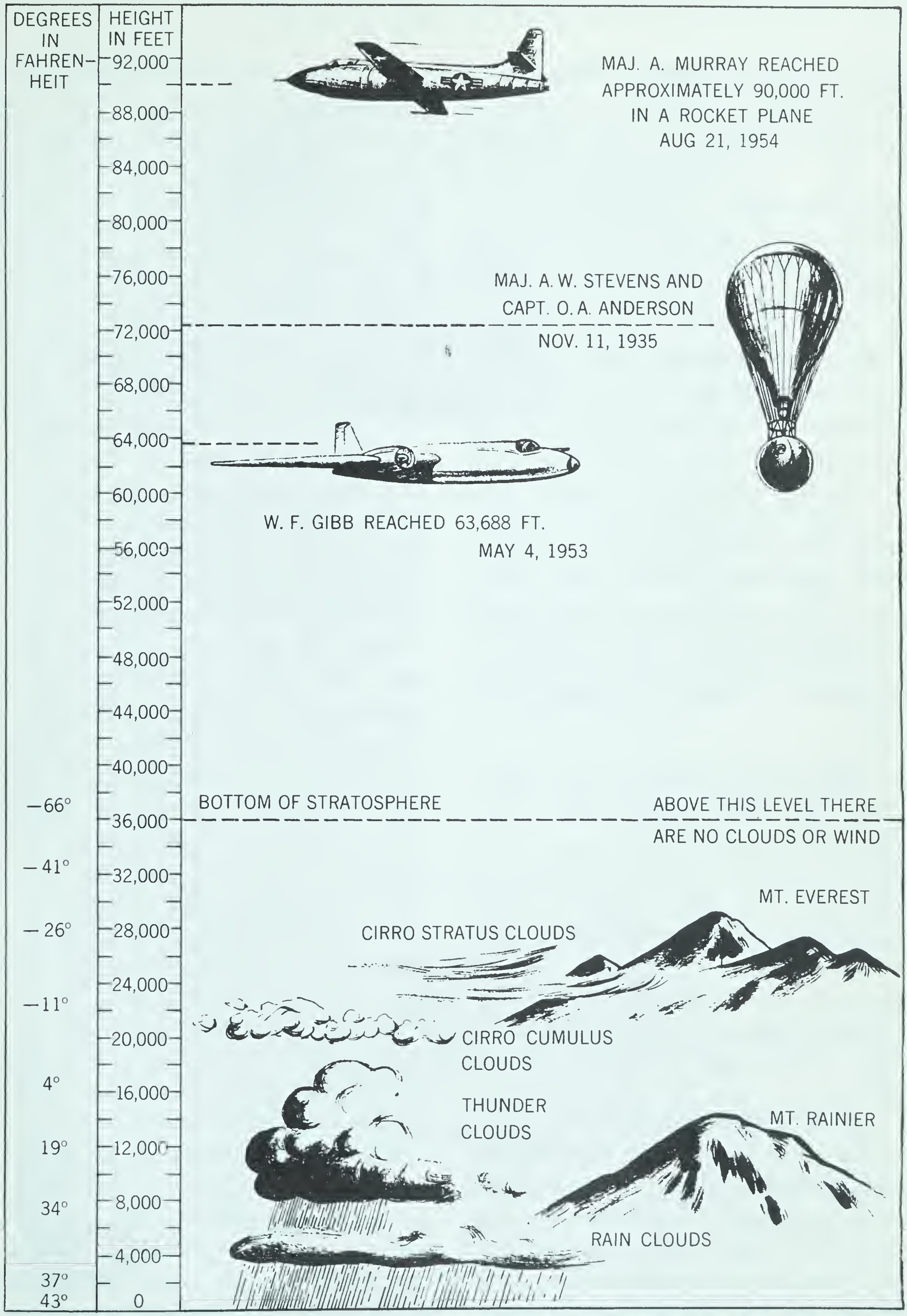


Fig. 5-2. This shows a diagram of the atmosphere. Compare the altitudes reached by the various aviators.

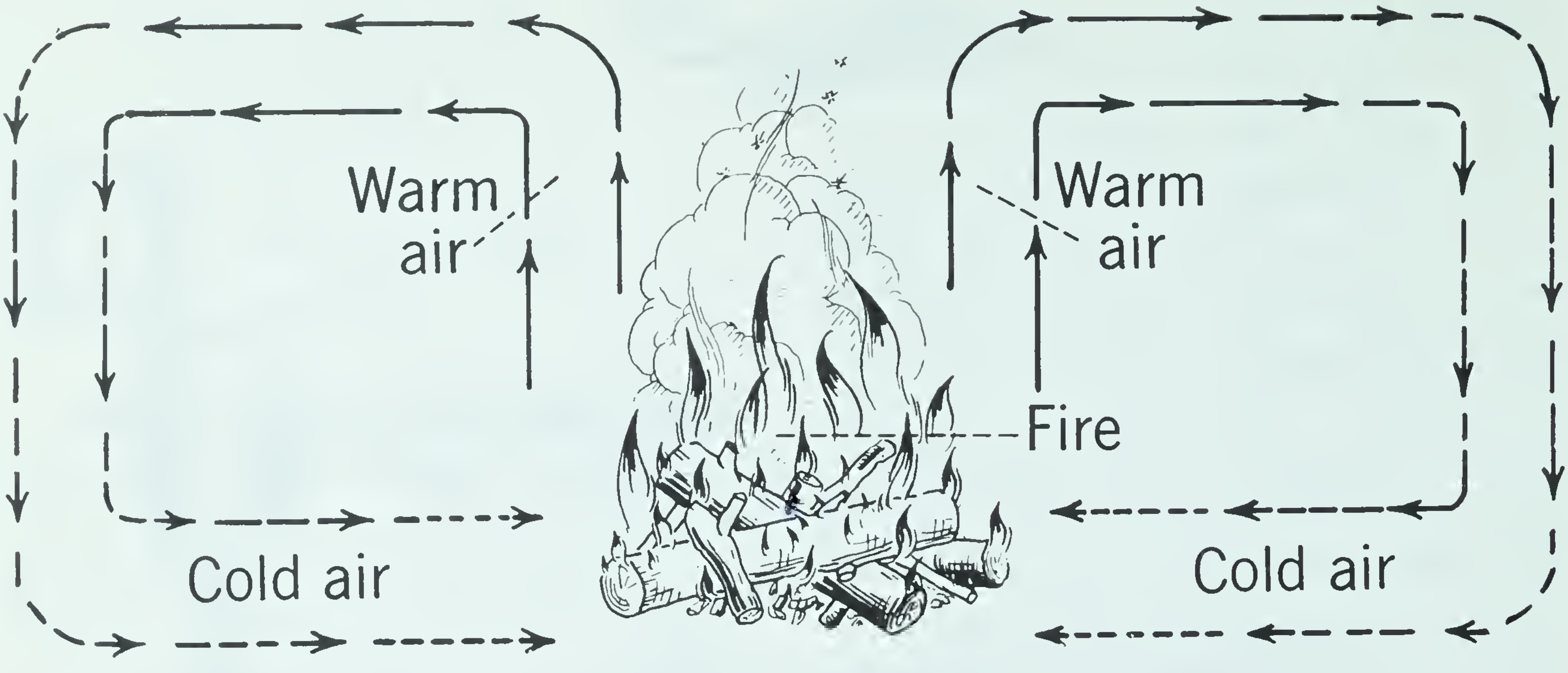


Fig. 5-3. A fire sets up currents of air similar to wind production on a small scale.

point. Notice the space above the spout. Notice the steam forming. Place a glass plate in the column of steam. Notice the condensation of the steam on the glass. Notice the height at which the steam disappears as it turns into invisible water vapor.

This process of forming water vapor from liquid water is taking place every hour of the day over the whole of the earth's surface. The sun warms the moist soil. The water in the moist soil evaporates, forming water vapor. The invisible water vapor thus formed enters the air. Water, from small pools to great oceans, is continually changing from liquid water to gaseous water vapor.

Clouds are formed when water vapor in the air is cooled and condenses to form water droplets. If the cloud forms near the ground, it is termed a *fog*. Let us see how water vapor in the air may be cooled so as to condense and form clouds and fog. As air rises, it cools. As air cools, the water vapor condenses. As the water vapor condenses, droplets of water form. A collection of water droplets forms clouds and fog.

When air that is nearly saturated with water vapor (meaning that it contains nearly all the water vapor that it is possible for it to hold) is forced up the side of a mountain, or a very high hill, clouds will form. If nearly saturated air flows over a cold land surface, it will cool and the water vapor will condense to form fog. If the fog forms in a valley, it is termed *valley fog*; if it forms in a shallow layer near the ground, it is termed *ground fog*; if it forms over the sea, or a large body of water, it is termed *sea fog. Remember that fog is simply a cloud that forms near the ground.*

Cold air is heavier than warm air. If you had two containers of the same size and weight and you filled one with cold air and one with warm air, the one containing the cold air would weigh more than the one containing the warm air.

DEMONSTRATION

Blow some smoke over a lighted candle or some other source of heat. Notice that the smoke rises. The smoke rises because the air over the candle flame is rising. The air over the candle flame becomes heated. As it becomes heated it expands. As it expands it becomes lighter. Being lighter than the cooler air surrounding it, the warm air rises. Therefore we can see that warm air is lighter than cold air. Conversely, cold air is heavier than warm air.

If a mass of warm air that contains nearly all the water vapor it can hold comes into contact with a mass of cold air, the warm air will flow over the top of the cold air. The cold air, being heavier than the warm air, acts like a mountain or a very high hill with respect to the much lighter warm air. Conversely, if a mass of cold air moves towards a mass of warm air, the cold air will flow underneath the warm air, forcing the warm air upwards. In both cases warm air containing water vapor is forced to rise and as it rises it cools, resulting in the condensation of water vapor which forms clouds.

On warm summer days you may have noticed many small, white, fluffy clouds moving slowly across the sky. It is on such days that miniature whirlwinds (*dust devils*) can be seen which cause spirals of dust to form and pick up pieces of paper and dry leaves and toss them into the air. These small fluffy clouds are caused by warm air from the surface of the earth rising upwards. The ground being heated by the sun in turn heats the air in contact with it. This heated air expands and becomes lighter. Being lighter than the surrounding air, it moves upwards. As it moves upwards, it cools. As it cools, the water vapor condenses out, forming white, fluffy clouds.

Now we know how clouds and fog are formed. The air cools so that the

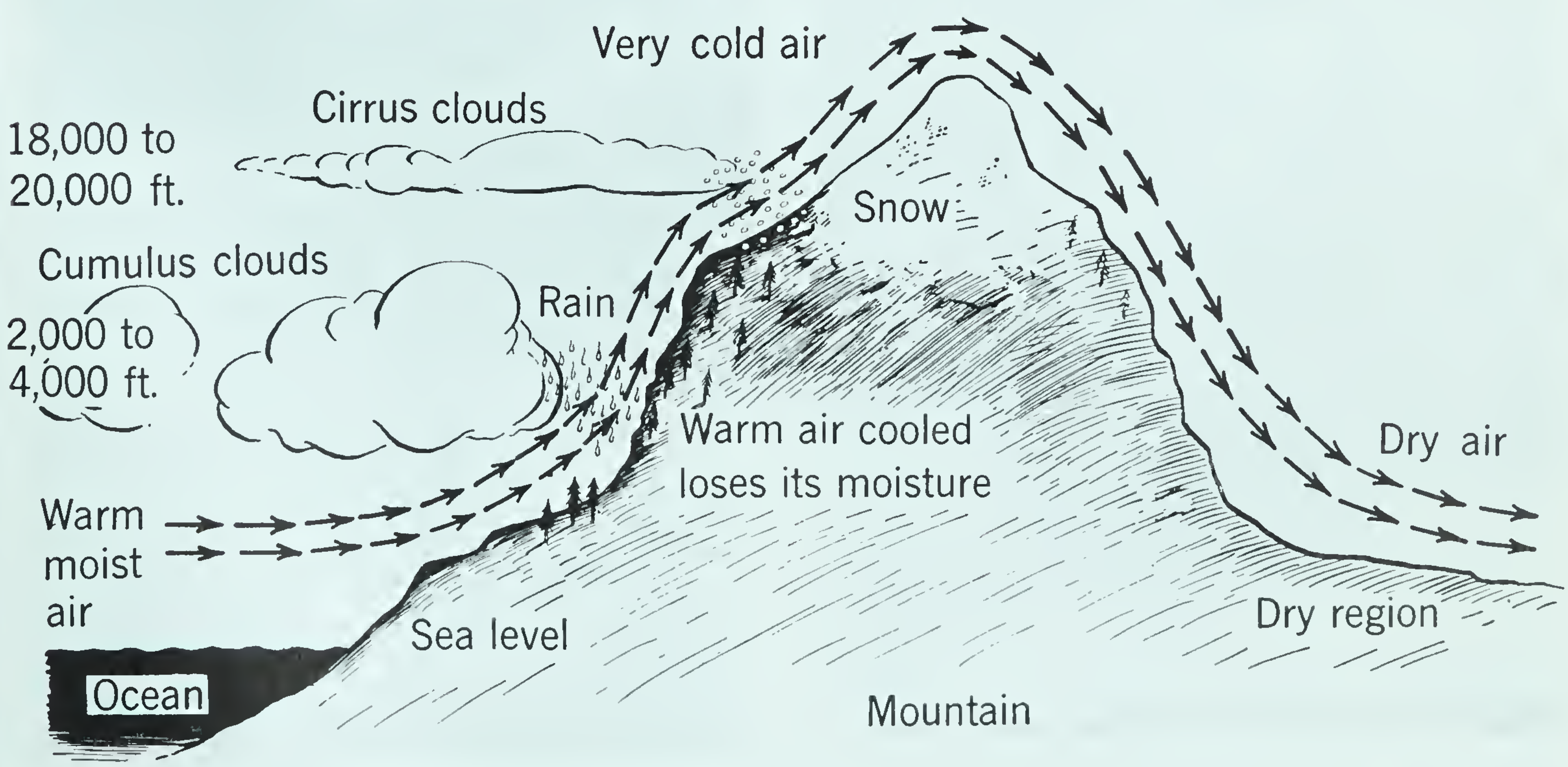


Fig. 5-4. Rising air currents become cooler and lose their moisture as rain or snow. Descending air currents become warm and absorb moisture.

water vapor condenses to form small water droplets. Air cools as it rises. Air in motion is forced to rise by being pushed up the side of a mountain; by flowing over a mass of heavy cold air; by being pushed upwards by a mass of advancing heavy cold air; or by being heated by the earth that is heated by the sun.

PUPIL ACTIVITY

Fill a transparent glass with cold water. Add some ice or snow. Notice water droplets forming on the outside of the glass. How do you explain this? Place a thermometer in a glass of cold water and add snow or ice. When water droplets form on the outside of the glass, take the reading of the thermometer. This temperature is known as the *dew point temperature*. It indicates the temperature to which the air in the room must be cooled in order to cause the water vapor to condense out to form water droplets.

REVIEW QUESTIONS

1. What is water vapor? **2.** Name three ways in which water vapor can be formed from liquid water. **3.** What is meant by condensation? **4.** What is steam? **5.** What is the difference between steam and clouds? **6.** How are clouds formed? **7.** What is fog? **8.** Name three kinds of fog. **9.** Which is heavier, cold air or warm air? **10.** If a mass of cold air meets a mass of warm air, will the cold air go under the warm air or over the top of it?

What are the different kinds of clouds? Our *atmosphere* (the air surrounding our earth) extends from the surface of the earth to a height of many hundreds of miles. This extensive layer of atmosphere has been classified into two distinct zones. One zone is termed the ***troposphere*** and it is that portion

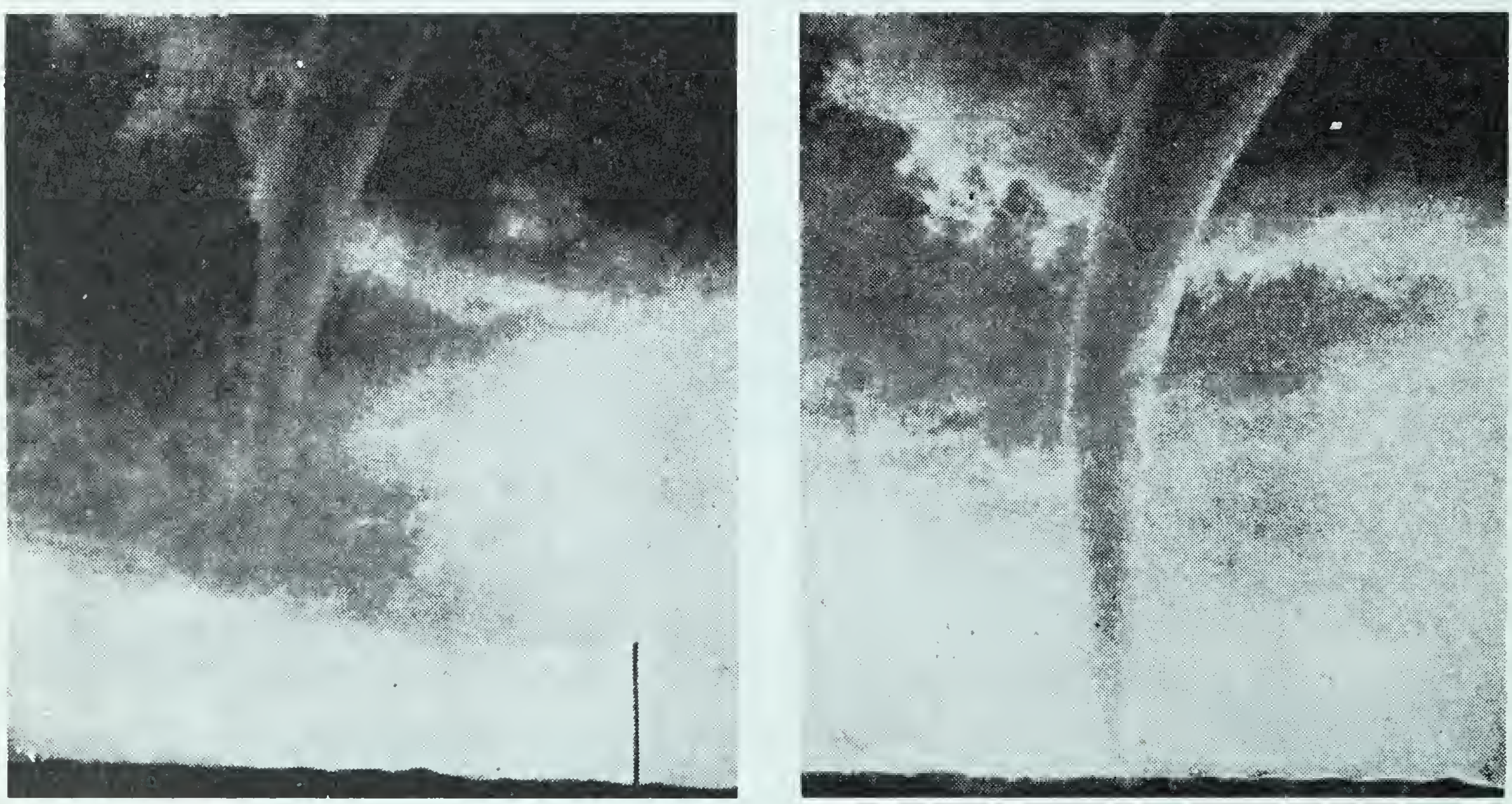


Fig. 5-5. In a tornado, the speed of the wind is extremely high, but only covers a small area.

of the atmosphere which extends from the surface of the earth to an average height of eight to nine miles. The zone extending to heights beyond the troposphere is termed the ***stratosphere***. *All clouds are formed in the troposphere and they are classified according to the height at which they occur*, as follows:

Low clouds. From near the earth to a height of 6,500 feet. *Cumulus, stratus, nimbostratus*, and *stratocumulus* are types of clouds that occur in this layer.

Middle clouds. From 6,500 to 20,000 feet. *Altostratus*, and *altocumulus* are types of clouds that occur in this layer.

High clouds. From 20,000 feet to 40,000 feet. *Cirrus, cirrostratus*, and *cirrocumulus* are types of clouds that occur in this layer.

Clouds of vertical development. These are clouds that extend, as a single cloud, from the surface of the earth to a height of from 20,000 to 40,000 feet. *Thunderstorm clouds* occupy such an extensive layer.

DEMONSTRATION

Draw a diagram on the blackboard showing the different cloud levels and the approximate appearance of the various cloud types.

PUPIL ACTIVITY

Cut out pictures of the different kinds of clouds that you will find in magazines and illustrated papers. Consult weather books, and your teacher, so that you may be able to name the different kinds of clouds in the sky from day to day. See if you can notice any relationship between the kind of cloud and the kind of weather being experienced.

B How are rain, snow and hail formed?

Rain, snow and hail are formed from water droplets. When minute water droplets in a cloud are drawn together to form a large droplet which is too heavy to remain suspended in the air, it falls as *rain*; if the temperature of the air is below freezing, instead of water droplets forming, ice crystals form. If a number of ice crystals mass together and fall to the earth, such a mass is termed a *snow flake*.

If a rain drop is caught in a strong upward current of air, such as is found in many thunderstorm clouds, it may be carried to great heights where the temperature is below freezing. The rain drop then freezes forming a small ball of ice. It may fall towards the earth again and as it does so, pass through rain and water droplets which increase the size of the ice ball by adding a film of water around it. Again it may be carried upwards, once again to be frozen into a larger ball of ice. This process may be repeated many times, until finally the ball of ice is so large that it can no longer stay in the air and falls as *hail*. Hailstones as large as golf balls are not uncommon.

Drizzle is a form of rain in which the rain drops are very small.

Dew is the condensation of water vapor on various objects on the earth's surface.

Frost is the formation of ice crystals

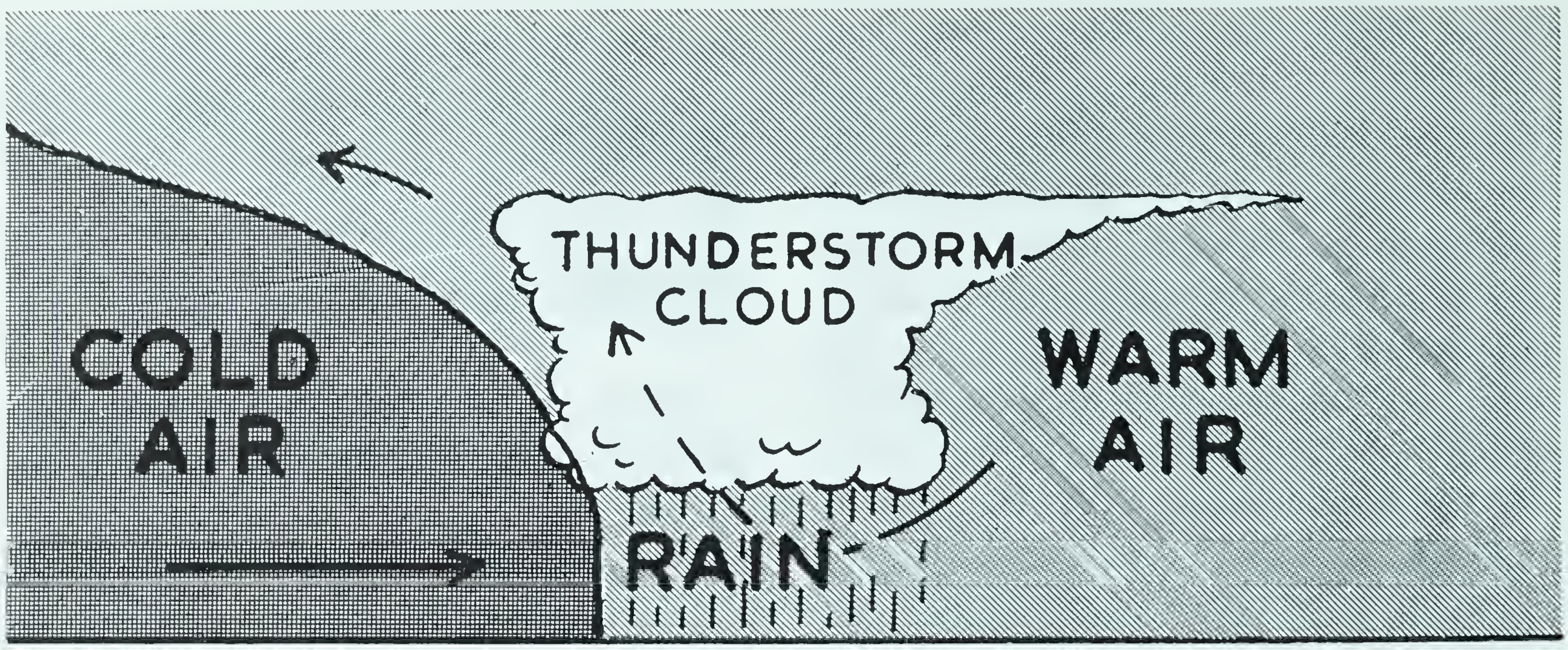


Fig. 5-6. Thunderstorm clouds usually form as cold air replaces warm air.

on various objects on the earth's surface.

Sleet is a mixture of rain and snow. In some parts of the world, as in Europe, sleet refers to the conditions when rain forms ice on contact with objects on the earth.

Cloud masses accompany thunderstorms. When air containing a great deal of moisture rises, it cools and as it cools the water vapor condenses to form water droplets. A large collection of such water droplets is termed a cloud if it is located above the earth's surface, or a fog if it is located at the earth's surface. If the cloud so formed has its base in the low cloud level, at approximately one to two thousand feet, and its top in the high cloud level, at approximately twenty to thirty thousand feet, we term this continuous cloud mass a *cumulonimbus or thunderstorm cloud.*

There are very strong winds associated with thunderstorm clouds, which, as you have no doubt read, are capable of tearing an airplane apart. When such strong winds extend from the thunder-

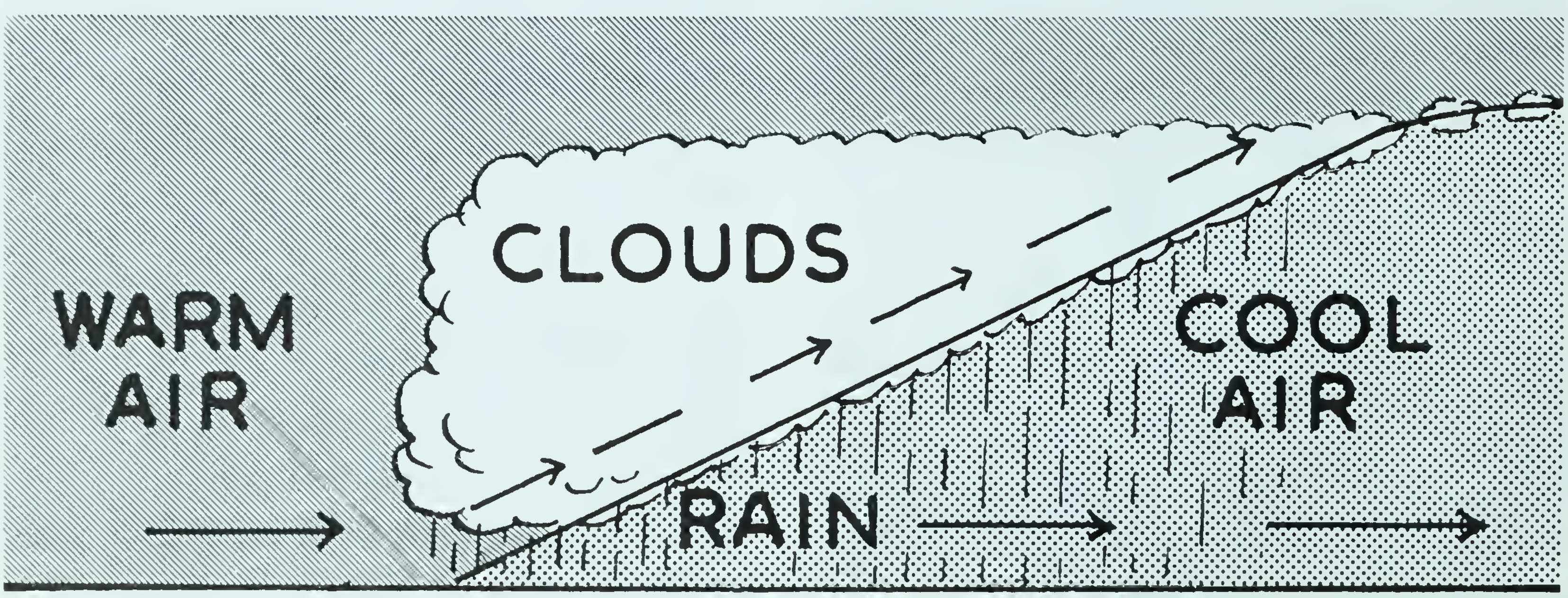


Fig. 5-7. A dense mass of clouds usually forms when warm air replaces cool or cold air.

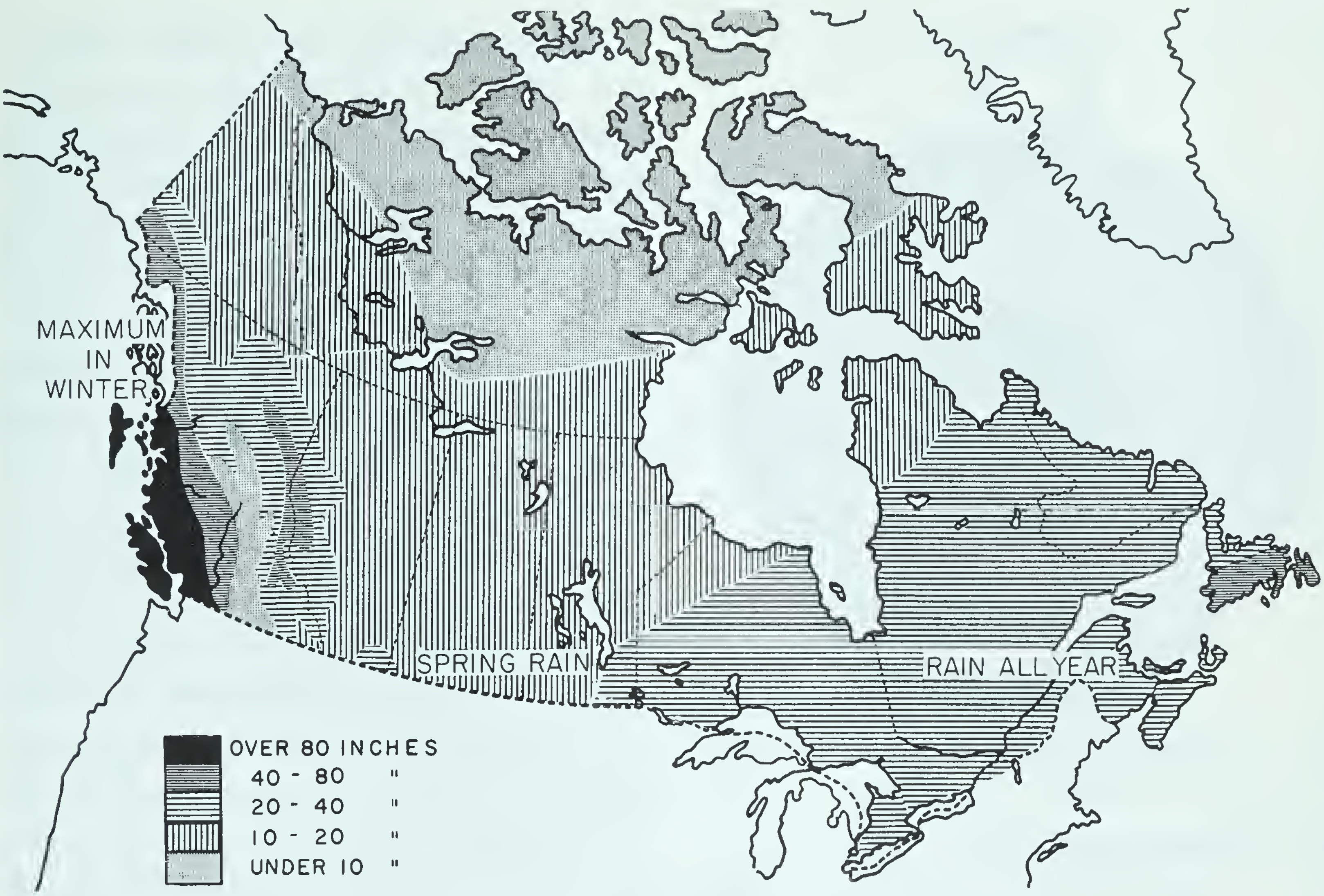


Fig. 5-8. The rainfall of any region is affected by mountains, direction of winds, and nearness to large bodies of water. What is the average rainfall of your region?

storm cloud to the surface of the earth, forming a cone-shaped structure, it is termed a ***tornado*** There are also powerful electrical discharges (*lightning*) which cause a vibration called *thunder*, as they pass through the atmosphere.

Since the strong winds in the storm cloud are capable of holding large water droplets in the air, heavy rain accompanies the passage of a thunderstorm cloud. Such large droplets may freeze to form balls of ice and so hailstones may also accompany the passage of a severe thunderstorm.

DEMONSTRATION

Draw a thunderstorm cloud on the blackboard. Indicate the following: anvil, scud clouds, updraft, downdraft, rain, hail.

REVIEW QUESTIONS

1. What is rain and how is it formed? **2.** What is a snow flake and how is it formed? **3.** What is hail and how is it formed? **4.** What is meant by each of the following terms: drizzle, dew, frost, and sleet? **5.** What is a cumulonimbus cloud? **6.** What characteristics are associated with a thunderstorm cloud? **7.** What is lightning? **8.** What is thunder? **9.** What is a tornado?

C Why is atmospheric pressure important?

Air has weight. As you learned in Unit 2, air has weight and exerts pressure.

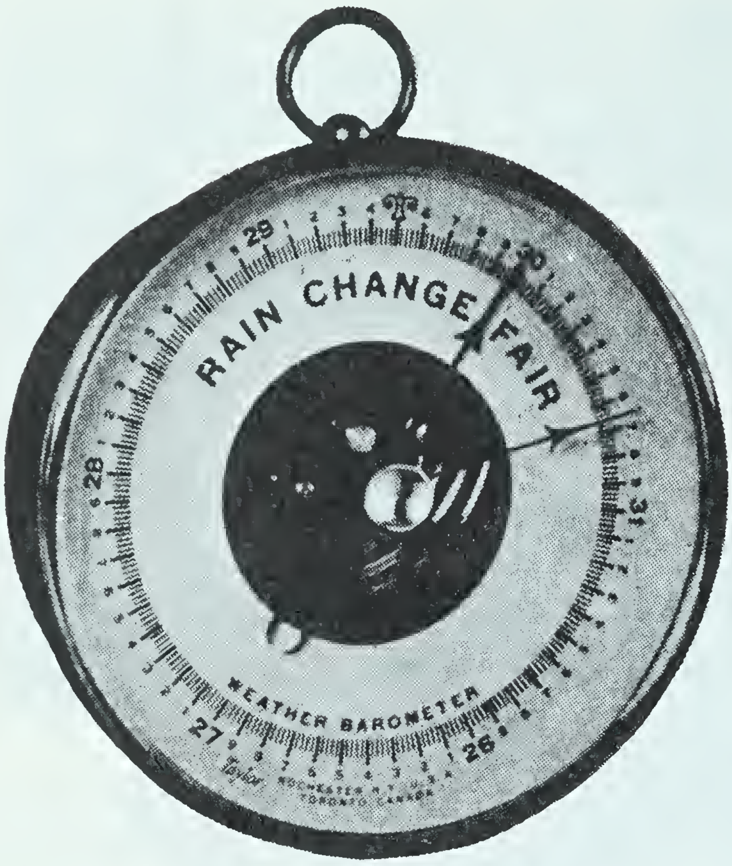


Fig. 5-9. Many homes have aneroid barometers like this one.

DEMONSTRATION

Place a piece of paper that has been ignited into a glass tumbler and invert the tumbler over a saucer containing water. Notice that the water rises in the tumbler. The reason is that the burning paper uses up the oxygen in the tumbler so that there is less air inside the tumbler. The weight of the air outside the tumbler forces the water from the saucer into the tumbler until the weight, or pressure, is the same inside and outside the tumbler.

This is the principle on which the mercury tube barometer, which you studied in Unit 2, operates.

The weight of the atmosphere is the cause of atmospheric pressure. If there is a great mass of cold air lying over the earth's surface, it will weigh more than a similar mass of warm air; because cold air, for the same volume, is heavier, therefore the atmospheric pressure will be greater.

Distributed over our earth's surface are masses of air of which some are cold, some cool, and others warm. This gives rise to areas of low pressure (for warm air) and areas of high pressure (for cool or cold air). Also, the depth of air varies over the earth's surface. Where there is a mass of air extending to a great height, it will weigh more than a similar mass of air that is not so extensive.

Barometers record atmospheric pressure. You have seen why this is so in the case of the mercury tube barometer. Another kind of barometer consists of a small metal container from which most of the air has been removed. As the atmospheric pressure increases, the sides of the container press inwards. As the atmospheric pressure decreases, the sides of the container expand. Attached to one wall of the container, by means of a delicate lever system and a fine spring, is a pointer. The pointer turns around on a dial somewhat like the hand of a clock and indicates the degree of atmospheric pressure. If the atmospheric pressure increases, then the pointer will indicate a greater reading (a higher number). If the atmospheric pressure decreases, then the pointer will indicate a smaller reading (a lower number). This type of barometer, known as an *aneroid barometer* (the word aneroid meaning without air) is commonly seen in houses. In addition to numbers on a dial indicating the atmospheric pressure, there are also such words as "stormy," "rain," "clear," and so on. If the pressure is rising, the pointer will indicate clear

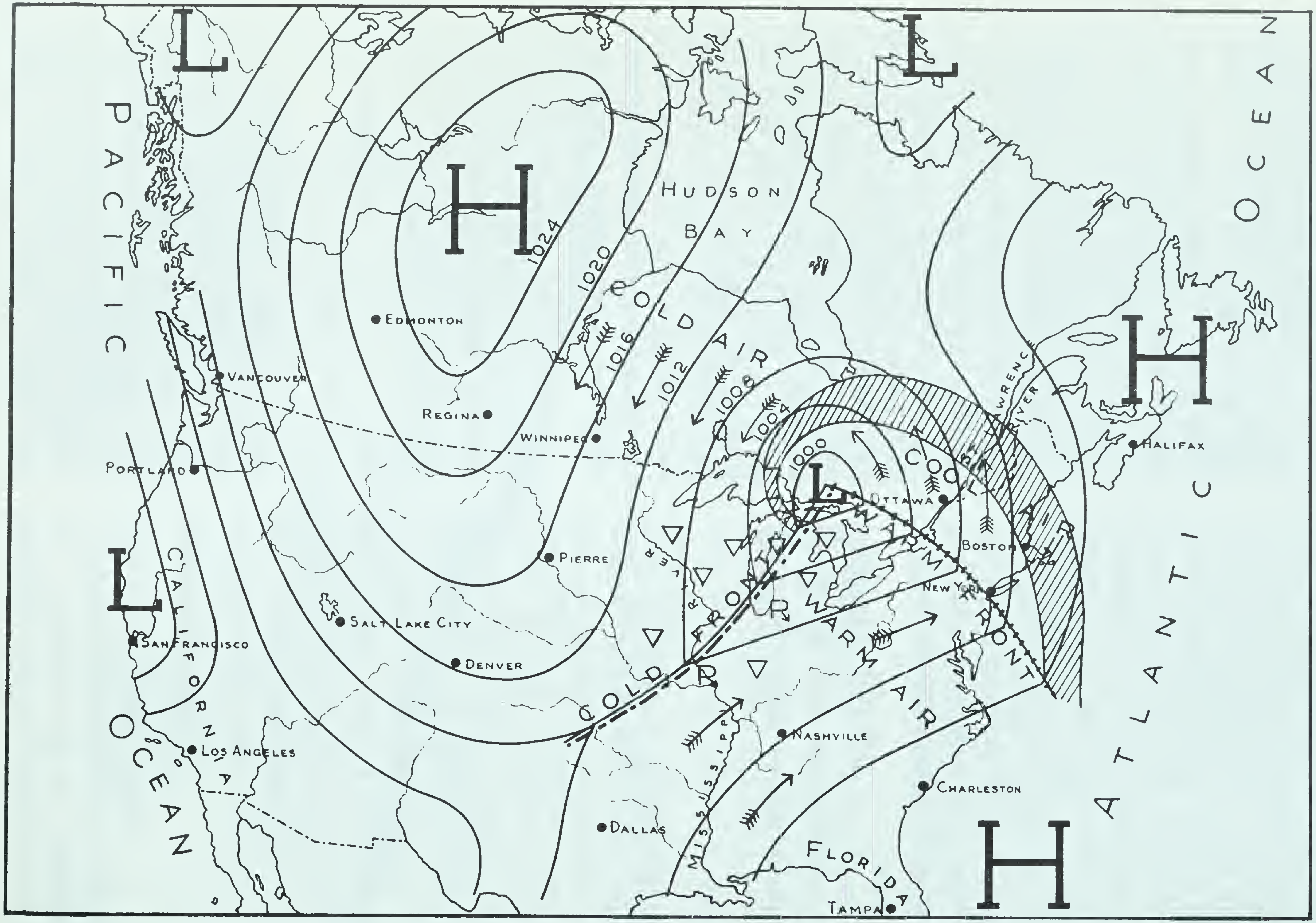


Fig. 5-10. A typical weather map showing the position of high and low pressure areas, warm front and cold front. △ sign indicates a shower; R sign indicates a thunderstorm; hatched area represents rain.

weather. If the pressure is falling, the pointer will indicate rainy or stormy weather. This is based on the fact that good weather is associated with high pressures and bad weather with low pressures. We shall learn much more about the importance of low pressures and high pressures in weather forecasting.

PUPIL ACTIVITY

Record the pressure readings on your school barometer from day to day. Make a daily record of the changes. Does fine weather follow a decrease or an increase in atmospheric pressure?

Weather maps show barometer readings throughout the continent. On the weather map (Fig. 5-10) notice the distribution of low pressure areas (L) and high pressure areas (H). Notice that these areas are made up of a series of concentric lines. These lines are termed *isobars* and are used to join localities that are experiencing the same atmospheric pressure at the same time. The numbers (1024, 1020, etc.) give the pressure along the line. The number 1020 means that there is an atmospheric pressure of one thousand and twenty millibars at every town and city located on this line. A *millibar* is a unit of pressure of the atmosphere, just as an inch is a unit of length and a pound a unit of weight. Notice that the largest numbers are in the center of the high pressure area and the smallest numbers are in the low pressure area.

The interaction of these low and high pressure areas gives rise to weather conditions and by studying these areas on a weather map the meteorologist (a scientist who studies the weather) is able to forecast the weather.

REVIEW QUESTIONS

1. Which weighs more, warm air or cold air? **2.** Why does water rise in a glass when the air has been partly removed by burning paper? **3.** Why does a liquid rise in a straw when you suck on it? **4.** What is meant by atmospheric pressure? **5.** What is meant by an area of high pressure? **6.** What is meant by an area of low pressure? **7.** What is a barometer? **8.** Name two types of barometers and explain the principles involved in their use as instruments for measuring air pressure. **9.** What is an isobar? **10.** What is the importance of isobars to the weather forecaster?

D What causes wind and why does it change?

What we call wind is air in motion. We have now seen how winds are formed in thunderstorms. We have also learned that when air becomes heated it rises and as it does so, cooler air rushes in to take the place of the ascending warm air, causing a cool *breeze*. If it is a very warm day, the breeze becomes much stronger and is termed a *gust*. If the air over the land is warm but the air over the water is cool, the cool air will blow gently towards the land. This type of breeze is termed a *sea breeze*. If the air over

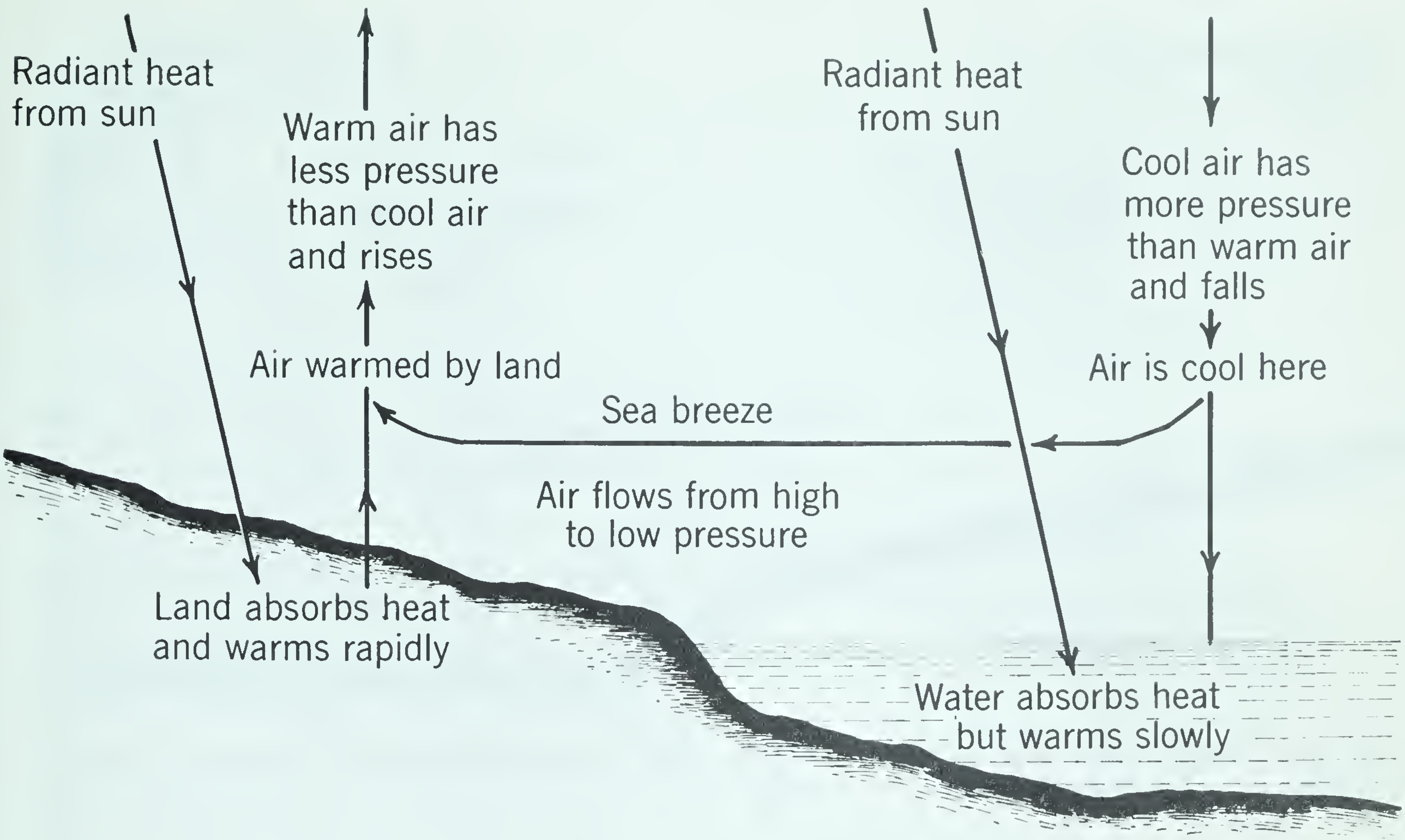


Fig. 5-11. This diagram shows how sea breezes occur. Compare conditions under which land and sea breezes are found.

the water is warmer than the air over the land, an off-shore breeze or *land breeze* will result. Sometimes the cool air from the top of a mountain will flow into the valley producing a *mountain breeze.*

In western Canada, on the east side of the Rocky Mountains, particularly in the provinces of Alberta and Saskatchewan, a warm, dry wind occurs known as a *chinook wind.* When the wind blowing from the west reaches the Rocky Mountains, it is forced to rise. As the wind rises, it cools and the moisture it contains condenses out to form clouds, and perhaps rain or snow may fall. When the wind blows down the mountain on the east side, it gets warmer as it descends. It is also dry because it loses much of its moisture on the west side of the mountain. Therefore, *a chinook wind is a warm, dry, mountain wind.*

Strong, continuous winds are usually associated with pressure areas. You will notice in the diagrams in Fig. 5-13 that the wind blows around an area of high pressure in the same direction as the motion of the hands of a clock. We say that the wind blows in a *clockwise direction around an area of high pressure.* The wind blows in a direction opposite to the hands of a clock in the case of the low pressure area, or we may say that the winds blow in an *anti-clockwise direction around an area of low pressure.*

Here is a good rule to follow. *If you stand with your back to the wind, the low pressure area will be located on your left and the high pressure area will be located on your right.*

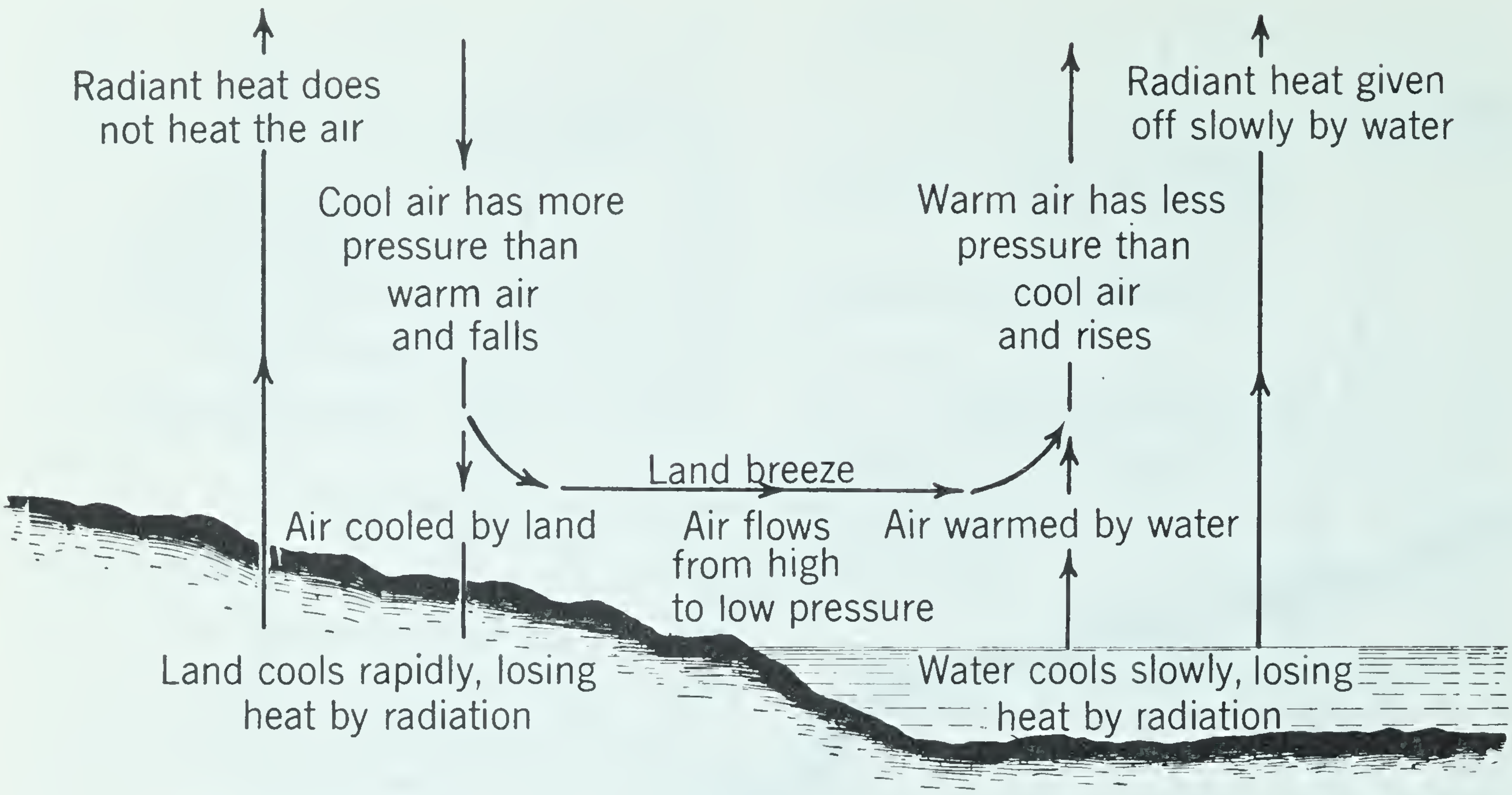


Fig. 5-12. Land breezes occur when the land is cooler than the water. The winds blow from the cool land toward the warmer water.

PUPIL ACTIVITY

When you leave the school, notice the direction of the wind. Stand with your back to it. Raise your left arm and point in the direction of the low pressure area. Raise your right arm and point in the direction of the high pressure area.

DEMONSTRATION

From the observations made by the pupils, make a simple diagram on the blackboard of the possible positions of low and high pressure areas in Canada.

Here is another interesting and important rule. *If the isobars are close together, the wind will be strong. If the isobars are wide apart, the wind will be weak.*

As the low and high pressure areas move across North America from west to east, the wind will change direction. Sometimes, as in the case of a low pressure area, the isobars may bend sharply. Hence the wind will change direction rapidly as the low pressure area moves over a certain part of the country.

REVIEW QUESTIONS

1. What is meant by each of the following: sea breeze, mountain breeze, chinook wind, gust? **2.** In what direction does the wind blow around an area of low pressure? **3.** In what direction does the wind blow around an area of high pressure? **4.** If you stand with your back to the wind, will the low pressure area be on your left or on your right? **5.** Are the winds stronger when the isobars are wide apart or when they are close together?

E Why are air masses important?

Air masses affect our weather. If the air comes from the north, it will be cold. If it comes from the south, it will be warm. If it comes from a great area of water, such as the Atlantic or Pacific Ocean, it will be moist. If it comes from a great area of dry land, such as the land mass in northern Canada, it will be dry. Therefore, air may be dry and cold, wet and cold, dry and warm, or wet and warm, depending upon where it comes from. These great bodies of air that have such important properties are termed *air masses.*

When two such air masses meet, weather is produced. Let us imagine that cold, dry air from the far north flows southward and meets warm, wet air that is flowing northward from the south Atlantic Ocean. The cold air, being heavier, as we have learned previously, will flow under the warm air causing the warm air to rise. As the warm, moist air rises, clouds are formed causing rain, snow, or sleet. If a thunderstorm should also form, hail may fall to the earth as well.

When two opposing armies meet on a battle field, the area of contact is called a front. The area of contact of two opposing air masses is also termed a *front.* As the low pressure areas move from west to east, so do the fronts.

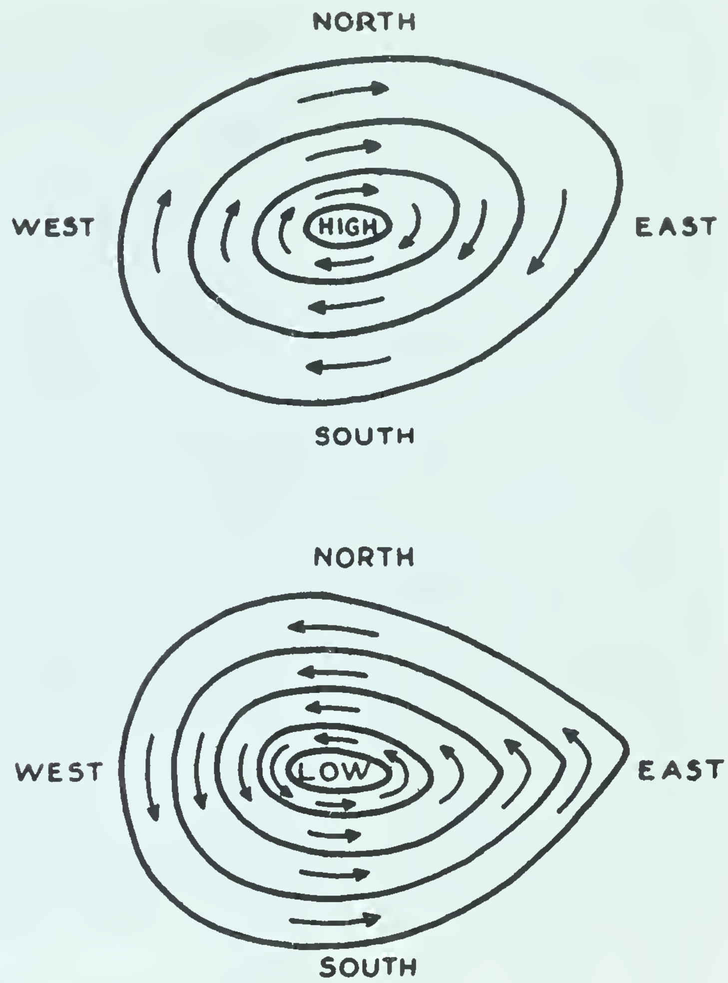


Fig. 5-13. Air moves about a high pressure area in a clockwise direction, and about a low pressure area in an anti-clockwise direction.

Fronts are always associated with low pressure areas. If a great mass of cold air replaces a great mass of warm air, we term the front a *cold front.* If a great mass of warm air replaces a great mass of cold air, or cool air, it is termed a *warm front.* After a cold front passes, the air becomes colder. After a warm front passes, the air becomes warmer.

DEMONSTRATION

Draw a typical warm and cold front on the blackboard. Indicate a number of cities and towns in your particular area. Indicate, by means of a series of smaller drawings, the changes that take place in the cities and towns as the low pressure area and its associated fronts move from west to east.

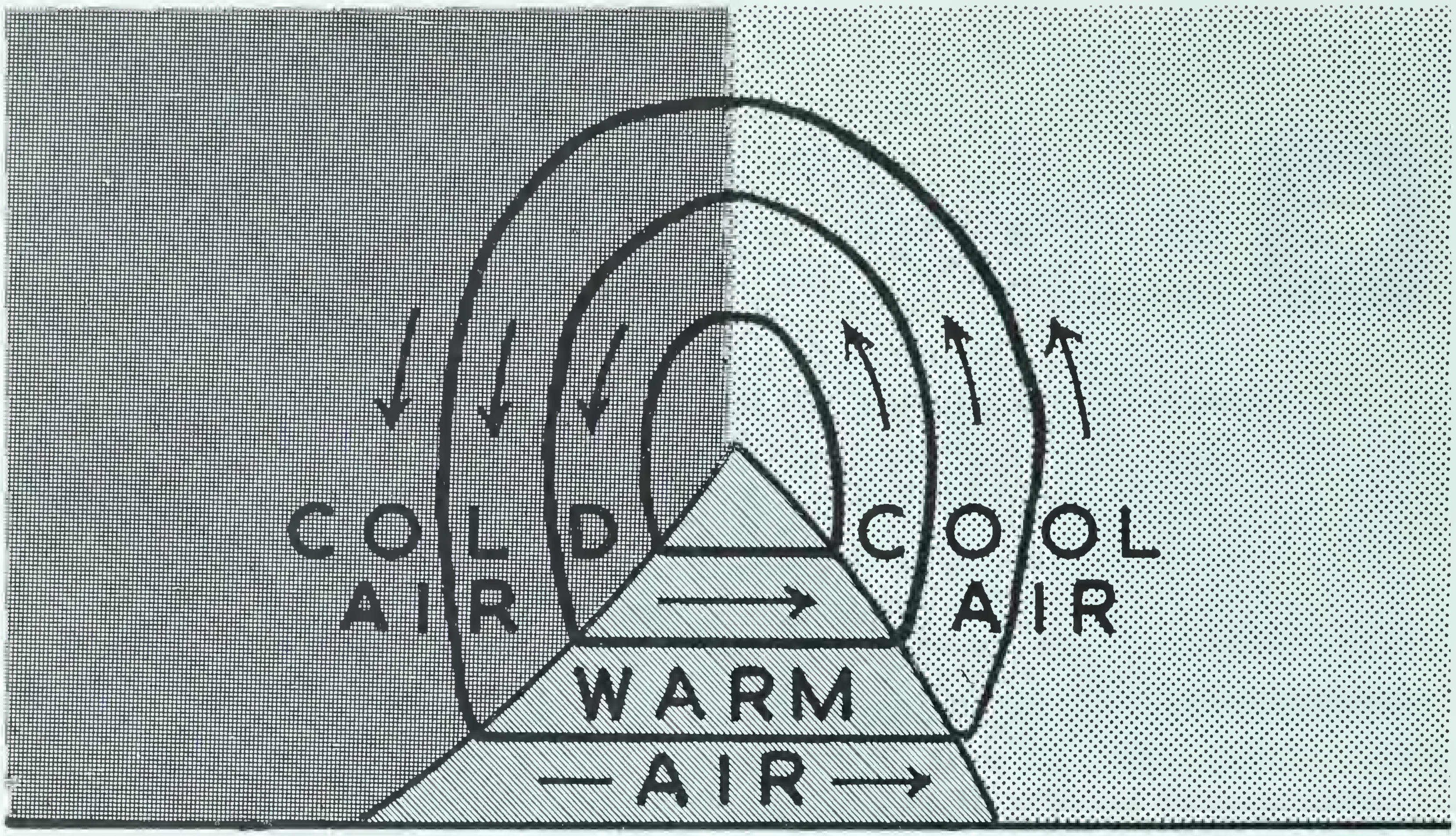


Fig. 5-14. Cold fronts and warm fronts are associated with low pressure areas. The area of warm air is termed the warm sector of the low pressure area.

PUPIL ACTIVITY

Make a record of the outside air temperature, wind direction, and the type of clouds for each day at the same time for a period of two weeks. Explain the possible causes for temperature changes, changes in wind direction, and appearance of clouds.

Cold and warm fronts bring different kinds of weather.

Cold Front. Examine the diagram that indicates a mass of advancing cold air (Fig. 5-6) and notice that the warm air is pushed upwards, just as if the warm air had come into contact with a very high mountain. Such a condition usually gives rise to the formation of thunderstorm clouds during the summertime, and high winds and blizzards during the wintertime. These thunderstorm clouds, or blizzard clouds, may extend for many hundreds of miles along the line of the advancing cold air or, as we now know it, the advancing cold front. Such a line of thunderstorm clouds situated along an advancing cold front is termed a *squall line.* Heavy rain, hail, thunder and lightning are usually associated with the passage of a cold front during the summertime. Heavy snow storms with high winds are usually associated with the passage of a cold front during the wintertime.

Warm Front. Examine the diagram that indicates a mass of advancing warm air (Fig. 5-7) and notice that the warm air flows over the top of the cold air causing a great heavy mass of clouds from which light to heavy continuous rain or snow falls. Light continuous rain, then heavy continuous rain, followed by drizzle and fog, are usually associated with the passage of a warm front during the summertime. Light

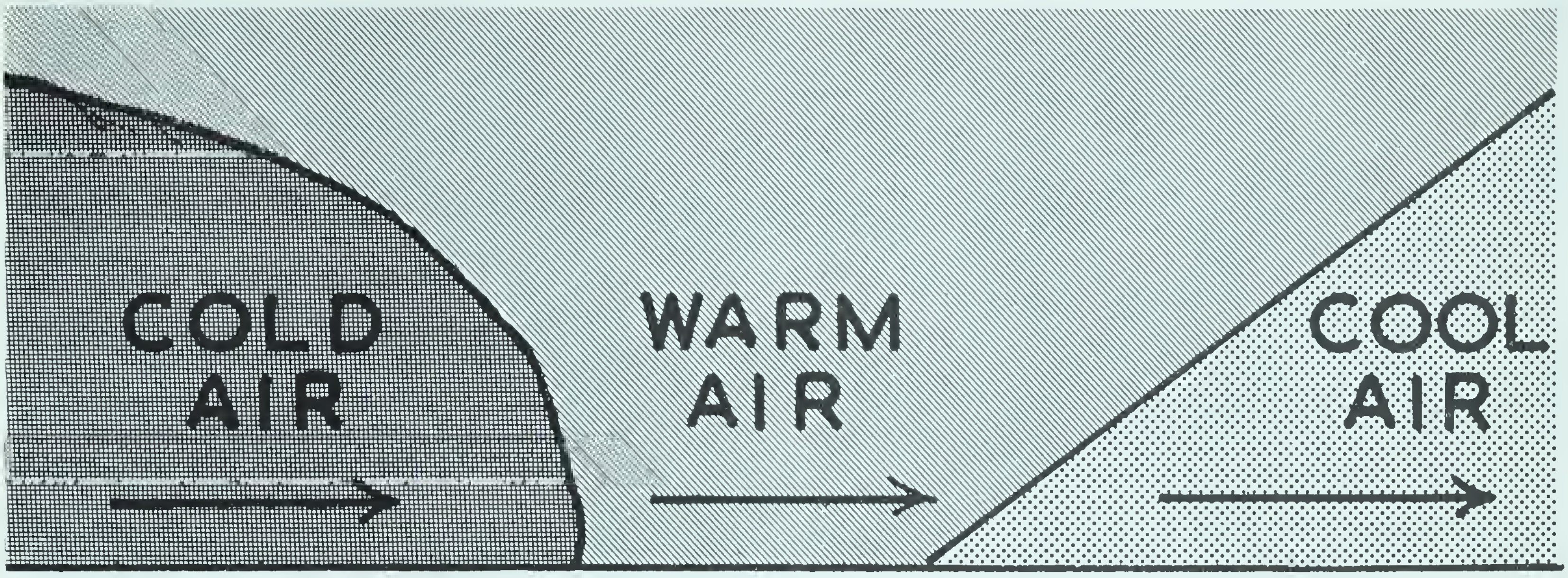


Fig. 5-15. Cold air replacing warm air gives rise to a cold front. Warm air replacing cold or cool air gives rise to a warm front.

continuous snow, then heavy continuous snow, followed by very light snow or snow crystals and fog, are usually associated with the passage of a warm front during the wintertime.

REVIEW QUESTIONS

1. What does the meteorologist mean when he refers to an air mass? **2.** What different kinds of air masses affect the weather of Canada and what are their properties? **3.** What is a cold front? **4.** What is a warm front? **5.** What happens when an advancing cold air mass meets a warm air mass? **6.** What happens when an advancing warm air mass meets a cold air mass? **7.** What is a squall line?

F How are weather maps drawn and used?

Weather maps record many observations. Situated in villages and towns throughout North America, there are hundreds of weather observers employed by the meteorological services of Canada and the United States. Such individuals make observations at specified times throughout a twenty-four hour period. They record such meteorological facts as the kinds of clouds, the amount of cloud covering the sky, the speed and direction of the wind, atmospheric pressure, air temperature, and weather conditions (rain, snow, sleet, fog, thunderstorms, etc.). Such observations are sent by means of a telegraph system to a central forecasting office. Here the information is recorded (plotted) on a map designed for that purpose. The weather forecaster, knowing the pressures at hundreds of places over most of North America, is able to draw his lines of equal pressure (isobars). Having located the isobars, he is able to locate the positions of low and high pressure areas. Knowing the kinds of weather, air temperature, and wind direction, he is able to draw in the positions of the warm and cold fronts in the low pressure areas. Having thus analyzed the weather for the whole continent of

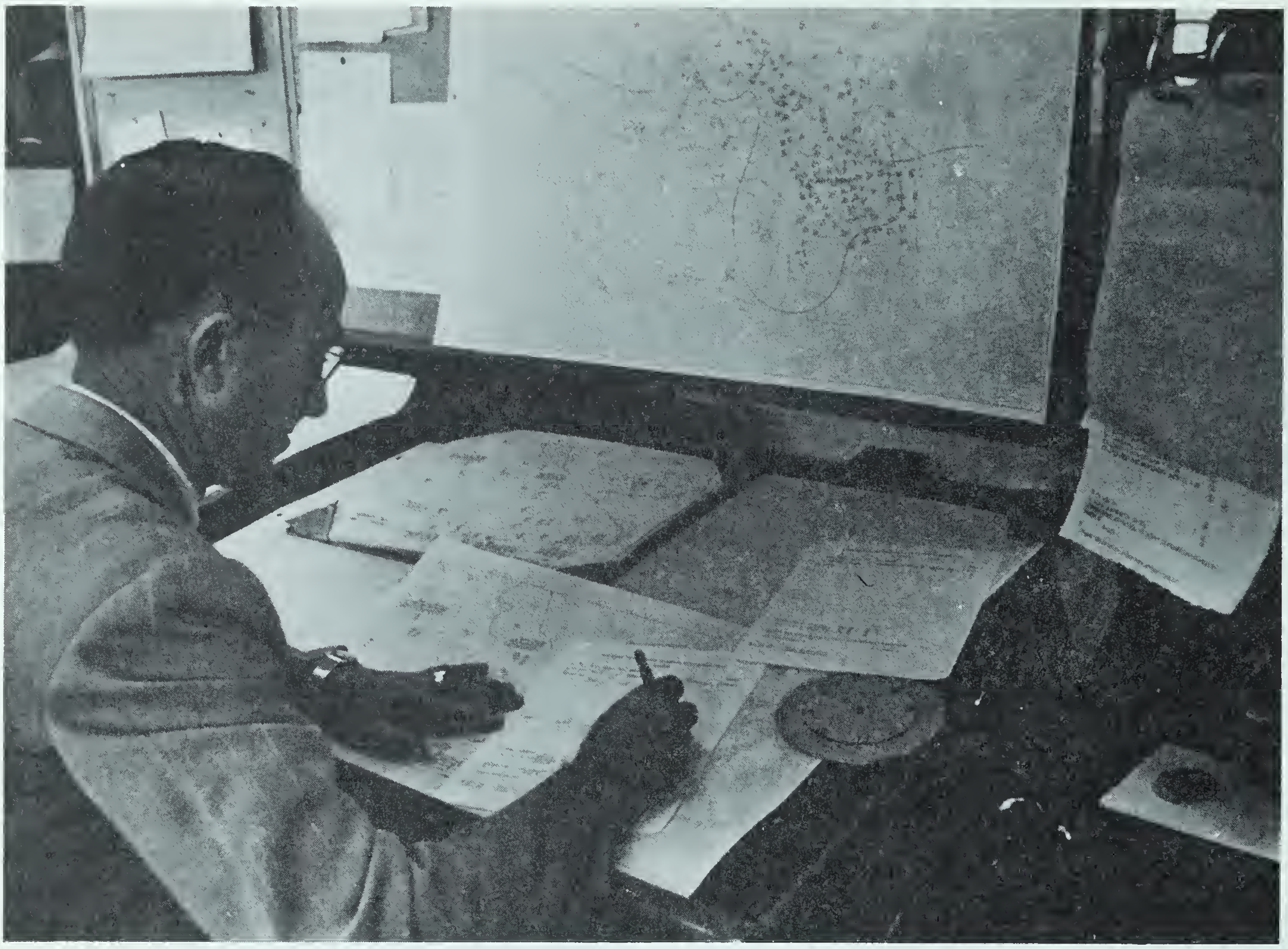


Fig. 5-16. To prepare this daily weather map, the weatherman must have accurate information from all parts of the country.

North America, he can predict, or forecast, what the weather will be like in any part of the continent as the pressure systems and fronts move eastward.

The movements of the pressure areas and fronts are recorded four times daily at intervals of six hours. In this way the rate at which the fronts and pressure systems are moving can be estimated. With this knowledge a forecast can be issued for a twenty-four hour period in advance. Such forecasts are sometimes referred to as "weather probabilities" because it is not possible, at least with our present knowledge, to forecast weather for a particular locality with complete accuracy. Many changes can take place. The fronts may move more rapidly than anticipated, or they may slow down or even stop. Various other factors, such as the effect of mountain ranges and large bodies of water, may alter conditions sufficiently to change the weather entirely.

At the present time, a great deal of research is being carried out on the properties of our atmosphere as they apply to weather forecasting. Hence, the methods used in weather forecasting are continually being improved, giving a greater degree of accuracy and enabling the forecaster to predict weather conditions for longer periods in advance.

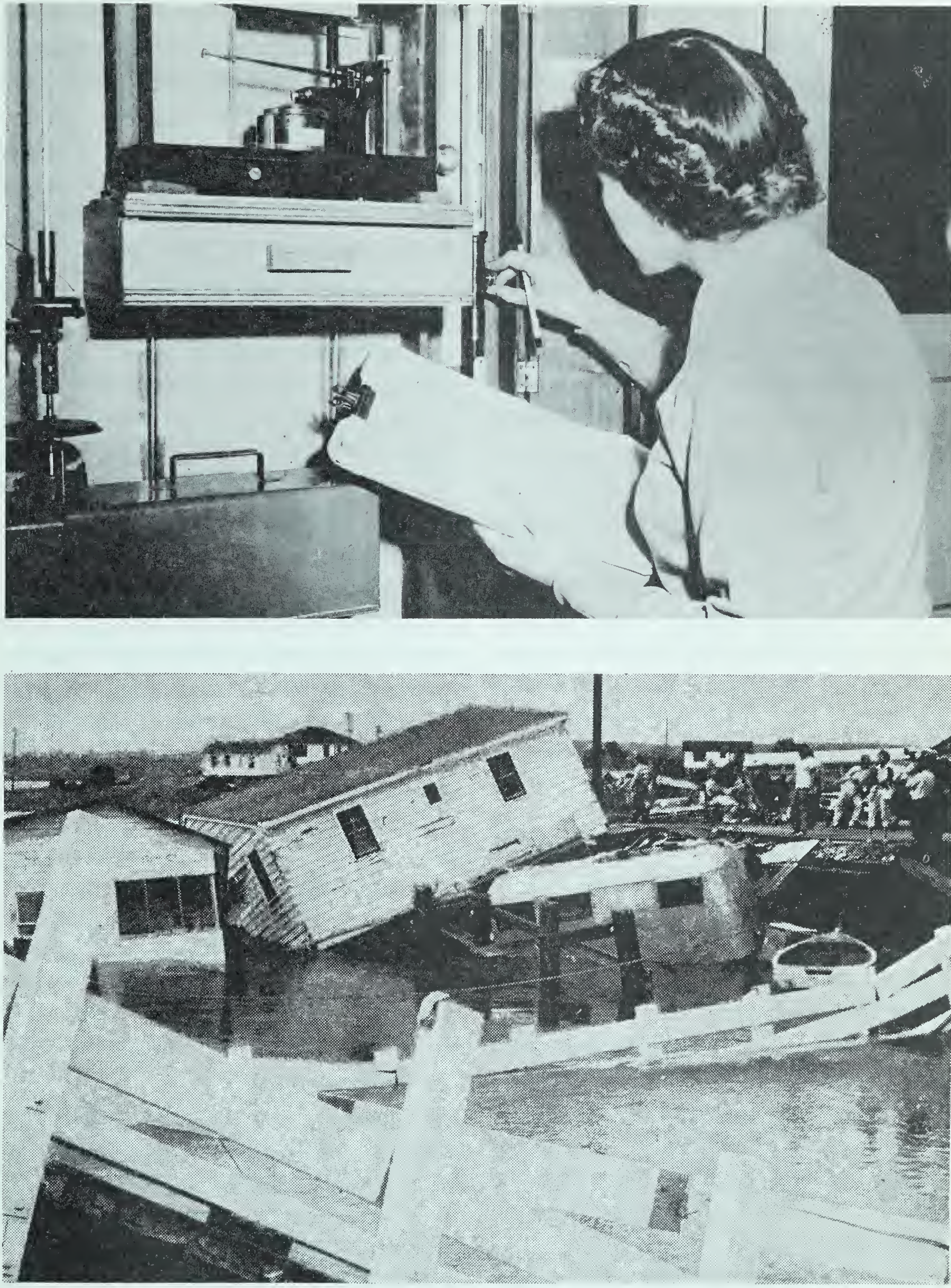


Fig. 5-17. The young lady in the top photograph is reading the barometer in a Dominion Meteorological office. Careful recordings are made which assist the weather forecaster to make predictions and, if necessary, to issue warnings of storms which may cause damage like that shown in the bottom picture.

G Can you forecast weather without a weather map?

You can sometimes predict weather. Although it is not possible to forecast weather accurately without a weather map, nevertheless there are certain signs that may indicate the kind of weather to be expected. For instance, you may have heard the old saying, *A bright sky at night is a shepherd's delight and a bright sky in the morning is a shepherd's warning.* Since you now know that pressure areas move from west to east and hence the weather must also move from west to east, you can better understand this saying by analyzing it as follows: If the sky is bright in the evening, just after the sun has set, you know that there are not likely to be any clouds of bad weather moving in from the west, because if there were clouds in the west, the sky would not be bright. If there is a bright sky in the morning, that means that there are no clouds to the east between you and the sun and hence there is a very good possibility of clouds being in the west. Therefore, a bright sky at night is a shepherd's delight because there are no fronts moving in from the west. A bright sky in the morning is a shepherd's warning because there may be clouds in the west, since there are none in the east.

You have no doubt heard that *mares' tails clouds are a sign of approaching bad weather.* Mares' tails clouds are very high clouds (cirrus) and they do herald the approach of an advancing front with heavier clouds and bad weather.

Thunderstorms cool the air is a well known belief. If a cold front passes your locality, there will be thunderstorms followed by colder air.

An east wind is a storm wind is another well known saying. If you examine the weather map, you will notice that the wind blows from the south-east ahead of the warm front. Near the surface of the earth the wind tends to be more easterly owing to the friction of the earth's surface. The wind direction indicated on the map is for a height of two thousand feet above the surface of the earth, at which height the friction of the earth does not prevent the wind from following the direction of the isobars. Winds in advance of the warm front tend to be more easterly. East winds herald the approach of a low pressure area with associated warm and cold fronts. Therefore east winds are storm winds.

So, you see, by observing the weather from day to day you can forecast changes without the use of a weather map.

DEMONSTRATION

Let us take a few examples of prevailing weather conditions as they may occur in your locality and, on the basis of these observations, forecast the weather for the following day.

Example 1: During the day the sky has remained clear. The sky was clear when the sun set. You examine your barometer

and find that the pressure has been rising steadily. During the morning the air was calm but gusts occurred in the afternoon.

Your forecast for the next day might be: Continuing clear with a few scattered clouds in the afternoon. Possibility of fog or dew during the night and early morning. Gusty conditions during the afternoon. Clear and calm in the evening.

Explanation: It will continue to be clear because the pressure was continuing to rise indicating that the high pressure area was still moving into your locality. A few cumulus clouds can be expected to form because during the day a clear sky would cause the air near the surface of the earth to become warm and this warm air would rise and form clouds. With a clear sky at night, the earth will become cool. This will cause the air next to it to become cooler, thus forming fog or dew. Gusty conditions would be caused by the warm air rising and the cooler air rushing in to take the place of the rising air.

Example 2: When you awoke in the morning you noticed that the sky to the east was clear. During the afternoon a few cirrus clouds began to form and a south-east wind became stronger. By evening the sky became almost completely overcast with thin high clouds (cirrostratus) so that the sun was dimly visible. You examine the school barometer and find that the pressure has been steadily falling.

Your forecast for the next day might be: Overcast skies with light to heavy continuous rain; moderate to strong south-easterly winds.

Explanation: Since the sun was shining in a clear sky during the early morning, it indicated the absence of any frontal system to the east. The cirrus clouds indicated the approach of a front which would in all probability be a warm front, since the pressure was dropping steadily, thus indicating the approach of a low pressure area and, as we have seen, the warm front precedes the cold front. You know that as the warm front approaches, the cloud mass becomes greater and hence the sky will become overcast. You also know that intermittent or continuous rain is associated with a warm front. With the approach of the low pressure area with its associated warm front, an increase in wind speed can be expected.

Example 3: During the past few days the weather has been clear and warm, following a period of light rain. Prior to the advent of the rain period, the wind was blowing from the south-west. This morning you notice that the sky to the east is clear, but to the north-west a few cirrus clouds can be seen. You examine the barometer, which has been remaining steady during the past few days, and you notice that the pressure has started to fall. By evening the sky is almost overcast with cirrus and there is a heavy mass of clouds to the north-west.

Your forecast for the next day might be: Cloudy to overcast sky; showers or intermittent rain; wind increasing in speed and changing direction from west to north; becoming colder.

Explanation: Since the weather in your locality has remained clear and warm following a period of rain, you realize that a warm front has passed and that you are now in the warm part of the low pressure area (that is the area between the warm front and the cold front, referred to as the warm sector). The pressure remained constant because, as you will

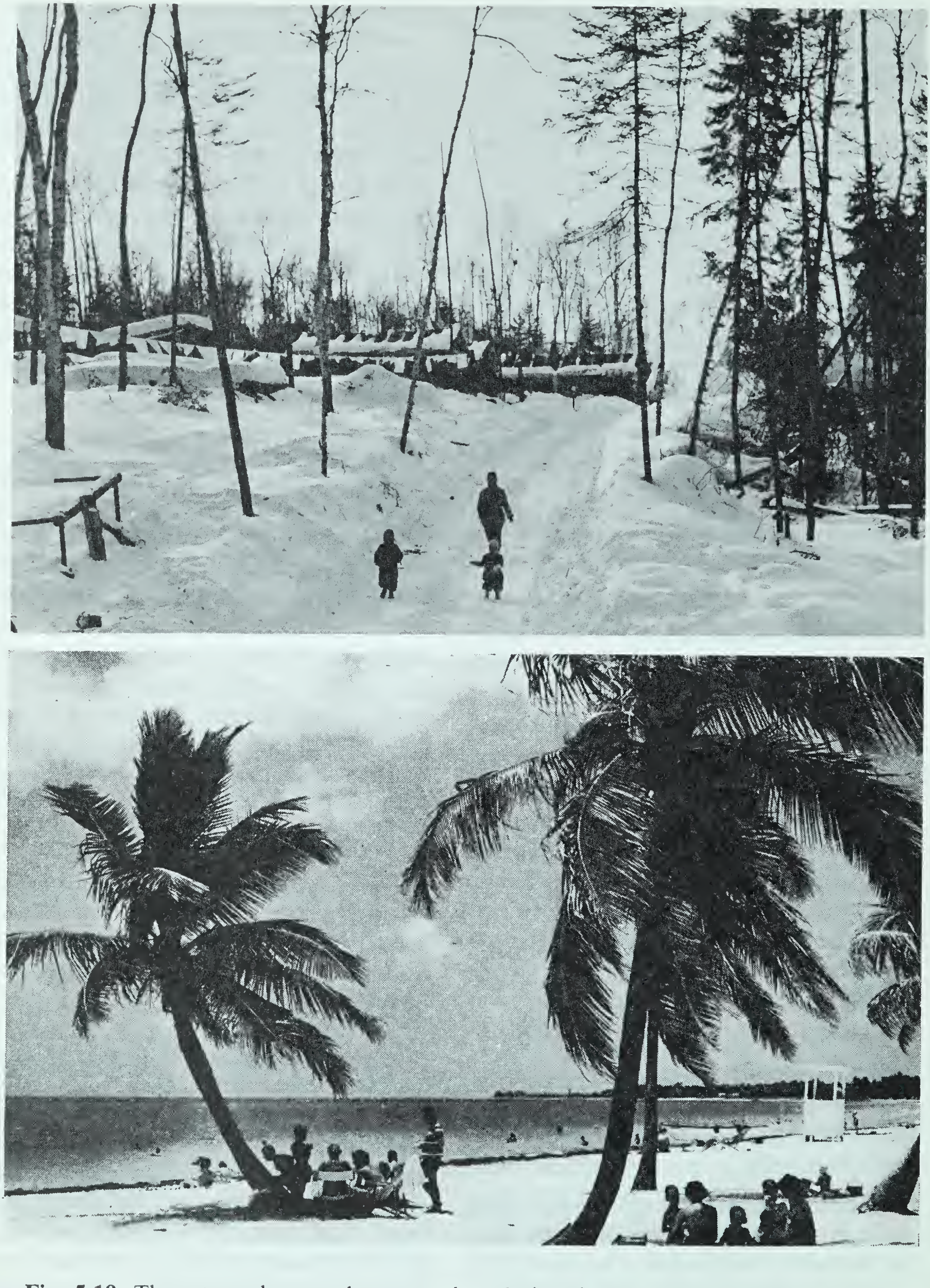


Fig. 5-18. These two photographs were taken during the same season, the top one in Quebec, the bottom one in Florida. How do you account for these extremes in climate?

notice in the weather map, the isobars tend to run east and west in the warm sector. With the approach of the cold front, however, the pressure starts to drop and the wind speed to increase. The presence of cirrus clouds would also indicate the approach of a front and the cloud mass to the north-west in the evening would further indicate to you that a cold front was approaching. You would forecast cloudy to overcast because during the passage of the front the sky would remain overcast but after it had passed the sky would start to clear, giving rise to cloudy conditions. After the passage of the cold front, your locality would enter the cold air behind the front and therefore you would forecast colder weather.

PUPIL ACTIVITY

From the observations made by the students during a period of three days, draw up a forecast explaining the importance of each observation.

QUESTIONS FOR REVIEW AND DISCUSSION

1. What are some changes that occur in the weather?
2. What precautions should be followed during a lightning storm?
3. What instruments are used for measuring atmospheric pressure?
4. What weather is usually associated with high pressure areas?
5. What is meant by a cold front?
6. What is meant by a warm front?
7. What simple rule will help you to remember the direction of the wind in a high pressure area and a low pressure area?
8. What kind of weather is usually associated with a warm front?
9. What kind of weather is usually associated with a cold front?
10. What is a weather map?
11. How is a weather map used in forecasting weather?
12. What causes moisture to condense?
13. What causes the formation of a sea breeze?
14. What is a chinook wind?
15. What effect do mountains have on rainfall?
16. What is the difference between weather and climate?

SPECIAL REPORTS AND PROBLEMS

1. Keep a daily record of temperature, pressure, wind direction, kind and amount of clouds, kind of weather, for a period of fourteen days.
2. From the daily observations made, attempt to forecast the weather for each day for a period of fourteen days. Compare your forecasts with those given in the daily newspapers or on radio broadcasts.
3. Keep a record, in a special weather notebook, of the forecasts that appear in the daily newspapers and check the accuracy of such forecasts with what weather is actually experienced. Make a note of the degree of accuracy.
4. Collect pictures of the different kinds of clouds and label them.
5. Enquire from your local weather office what forecasts are issued to aviators prior to taking off. Note the significance of these forecasts from the aviator's point of view.

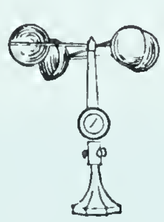
TESTING THE PURPOSES OF THIS UNIT

1. Discuss the circulation of water in nature, through the processes of evaporation and condensation (water cycle).
2. Discuss the effect of weather on driving conditions.
3. How are your daily activities influenced by weather conditions?
4. Why is it important to have a weather map in order to obtain an accurate weather forecast?
5. What is meant by each of the following words or terms: meteorologist, low pressure area, condensation, cold front, warm sector, fog, drizzle, troposphere, cirrus, snow flake, aneroid barometer?

The old

IN EARLY TIMES STORMS WERE BELIEVED TO HAVE BEEN SENT by the gods as punishment for some wrong which had been committed. As instruments like the barometer, thermometer, and the instrument for measuring wind velocity were invented, men began to see some relationship between the readings of these instruments and the conditions of the atmosphere. They soon learned that storms traveled in more or less regular paths and were always accompanied by definite atmospheric conditions. They felt sure that, by observing these conditions in advance, they could predict the weather.

The new



EACH YEAR WE LEARN MORE ABOUT THE CHARACTERISTICS OF the sun, and acquire more knowledge about the upper atmosphere. Scientists are inventing newer and more accurate instruments. The continuous reporting by airplanes of the weather conditions in the upper atmosphere is leading to safer flying and making longer flights possible.

But weather predictions, to be at all accurate, must be based on readings and reports from a large area. The Meteorological Service of Canada gathers weather information from all parts of the country. It can predict weather conditions rather accurately for several days in advance. Thus we can prepare against sudden changes in temperature and against storms. Once again, science has helped mankind to live more comfortably.

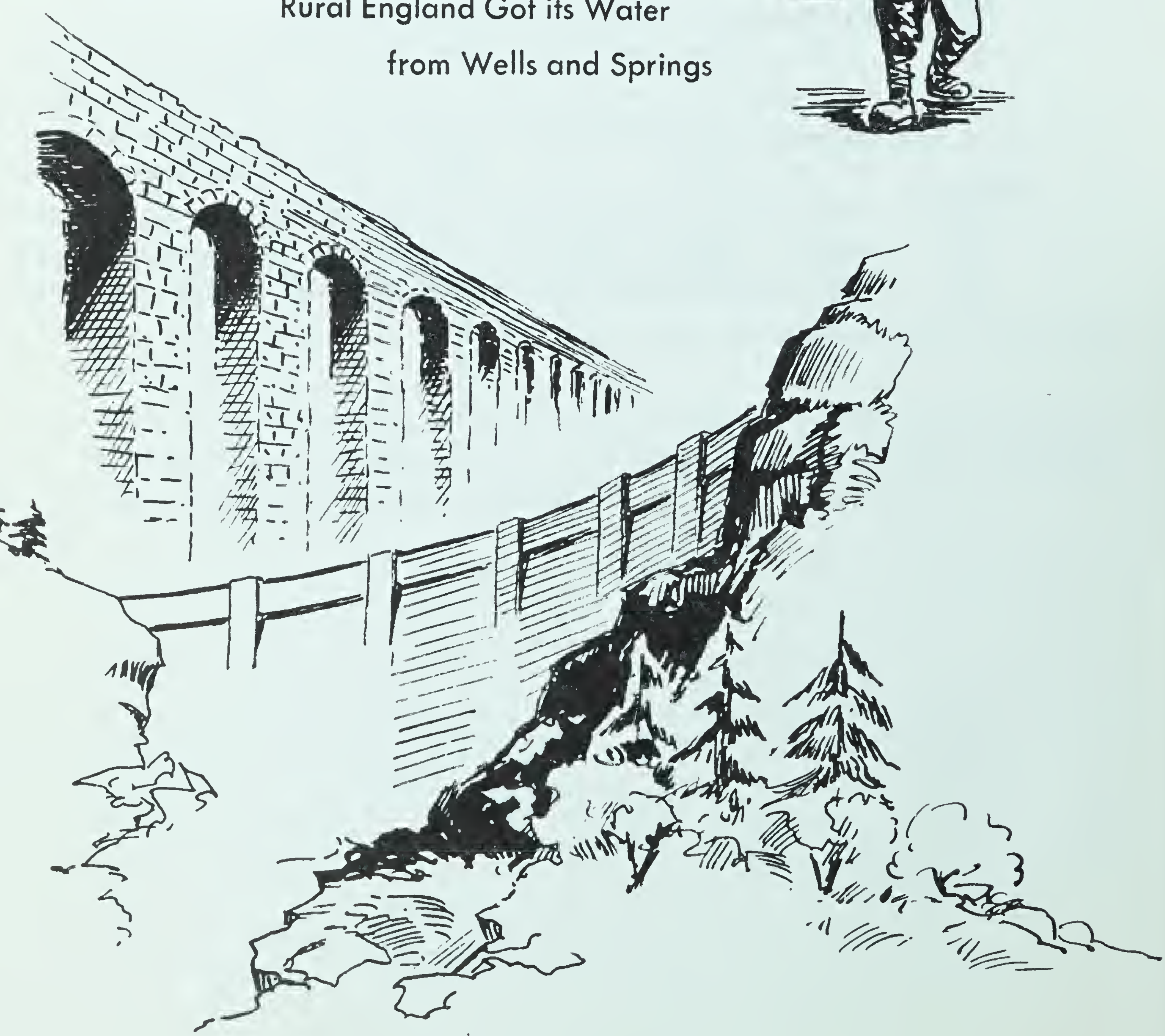
In the Desert, the Oasis

Is the Source of Water

In Asia, Water Is Carried from a River

Rural England Got its Water

from Wells and Springs



UNIT 6

How has man learned to obtain and purify the water he needs?

DISCOVERY AND PROGRESS

MAN cannot live without water. Early man got fresh water by building his home near a stream, lake, or spring. Because he lived far from any neighbors, the safety of the water was no great problem. Actually, there was nothing to make it unsafe. However, as civilization advanced, people began to live closer to each other. Then their water supply often became polluted. Eventually people realized that polluted water caused disease. They also found that if they lived far from a water supply, they had to build some kind of system to carry it to their homes.

In early days, people on the island of Crete made pipes of clay to carry

water to their homes. Ancient Greeks even built *aqueducts* (*ack*-wee-ducts) which carried water quite a distance. The Greeks also knew that the water must be kept safe.

Perhaps the most interesting water system of early days was the Roman one. These people built enormous aqueducts of brick and stone, the remains of some of which are still standing. One aqueduct brought water more than 50 miles from the Apennine Mountains into Rome.

In the early days of America when people lived far apart, there was plenty of safe drinking water for everyone. Then, as the population increased, towns and villages sprang up. Waste materials often got into the water supply and polluted it. Eventually, it became dangerous to use any water unless proved by testing to be safe.

In some cities in Asia Minor and other parts of the world, the water supply is still dangerous. People take water from rivers and lakes without any thought of possible pollution.

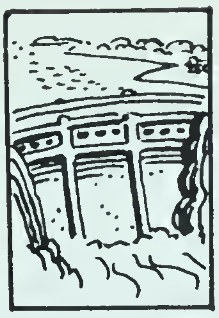
The chief danger of impure water is from the disease germs it contains. They enter the water in waste matter from those who have some disease. Of the many such germs in impure water, the one causing typhoid fever is perhaps the most common. You can get an idea of the severity of this disease by reading the report of deaths in the Spanish-American War. More men lost their lives from typhoid fever than from battle injuries.

Civilized man has made remarkable progress in controlling the natural sources of water supply. He has learned that forests are important in maintaining a steady supply of water, so he protects them and plants trees to replace those that are cut down or lost in forest fires. He has learned to build huge dams, reservoirs, and systems of pipes to carry water to us, and sanitary plumbing systems to carry away waste matter safely. Most important of all, man has learned how to destroy disease germs in water, and to dispose of wastes without polluting drinking water.

The greatest problem now is to prevent the water in lakes and rivers from being polluted by sewage. Pollution also kills most of the natural forms of life.

Another serious problem is the lowering of the water level in many areas. The drainage of marshes has helped to improve some soils, but it has also contributed to lowering the water levels. In some areas it has become necessary to return these drained marshes to their original form to help maintain the balance between plant and animal life. In some places, the rapid increase in population has made it difficult to get a water supply sufficient for all uses.

We hope that in the future some cheap method will be found to remove salt and other minerals from sea water. If this can be done, the problem of finding pure drinking water in some thickly populated regions will be much simpler.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. Why is it important to have safe drinking water? **2.** What is the source of the water in your area? **3.** How is impure water made safe? **4.** How is water brought into your home? **5.** Why is the water in shallow wells likely to be impure? **6.** How are waste products removed from your home? **7.** How do chemists and druggists get pure water for their work? **8.** How can compressed air be used to lift water? **9.** How does soap help in cleaning? **10.** How does a modern plumbing system operate?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

bacteria . . . the smallest and simplest plants, seen only with a microscope.

chlorination (kloh-rin-*ay*-shun), the addition of chlorine to water which kills germs and helps make it fit for drinking.

coagulation (koh-ag-you-*lay*-shun), the formation, by chemical reaction, of a jellylike material in water, often used to remove fine sediment from water.

condensation (kon-den-*say*-shun), the changing of a vapor into a liquid by cooling.

distilling . . . (dis-*til*-ing), the process of purifying liquids by heating them until they form a vapor, and then condensing the vapor by cooling.

filtering . . . . a process for removing solid particles from a liquid by passing it through a fine sieve or other materials.

hard water . . water containing dissolved mineral matter which makes soap curdle.

organic . . . . pertaining to living matter or matter which was once living.

pressure . . . the force of water or some other substance against a unit of area, such as the square inch.

sewage . . . . the liquids containing wastes from homes and industries.

soft water . . water which is free of dissolved mineral matter; in which soap immediately forms suds.

A How does nature keep a constant supply of water?

Our water supply depends on the water cycle. Rain and snow fall from the clouds. This water either sinks into the earth or runs off in streams and rivers to lakes or oceans. Finally, it evaporates again into the air as water vapor and forms clouds. This series of events makes up what we call the *water cycle.*

DEMONSTRATION

Boil some water and when it reaches the boiling point let it continue to boil hard. Notice the cloud of steam that is formed as the water boils. This is really condensed water, since water vapor is invisible. Now hold a cold glass beaker or a drinking glass in the escaping steam. What do you see forming on the beaker? How does this demonstration compare with the water cycle in nature?

Water may fall to the earth in the form of rain, snow, hail, or sleet. These are all included in the general term ***precipitation*** (pree-sih-pih-*tay*-shun). The precipitation which falls on land surfaces of the earth may sink in, run off, or evaporate from the surface. Whatever runs off goes into streams or rivers and eventually most of it gets into lakes or the ocean. Evaporated water goes back into the clouds and later falls again as rain or some other form of precipitation.

The water that sinks into the soil is called ***soil water.*** Plants depend on this soil water to grow properly. Soil water also supplies wells and springs. The level of the soil water is called the ***water table.*** This is important to farmers or to anyone else who depends on wells and springs for a supply of water. During long, dry spells the water table may fall so low that wells can no longer

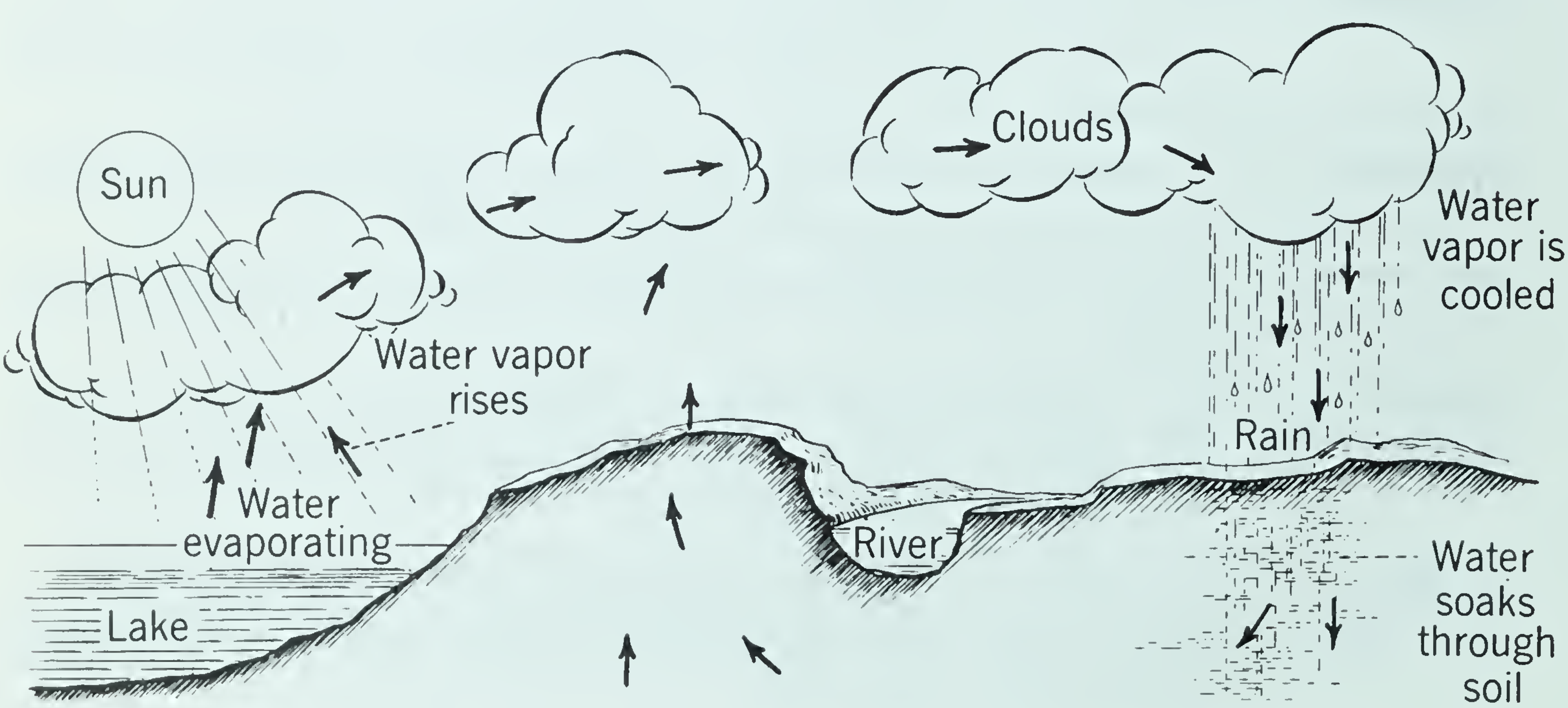


Fig. 6-1. Trace the series of events in the above diagram that make up the water cycle.

supply enough water for normal use.

Fresh water comes from: (1) rain water; (2) rivers and lakes; and (3) springs and wells. Mountain lakes and streams probably furnish the most satisfactory supply. The water from these sources is usually pure for human use. Rural communities and small towns often get their water from wells. But larger communities must use more elaborate systems to obtain their water supply.

Forests help to keep a steady supply of pure water. When it rains in a forest, the water does not run off quickly. It sinks into the loose spongy soil, which is composed largely of decaying leaves. This water then flows out gradually into clear streams which feed the rivers and lakes, instead of rushing down in muddy torrents.

Fig. 6-2. Built in 19 B.C., this Roman aqueduct still stands across a river in Nîmes, France. It brings in water a distance of 31 miles. It is 160 feet high and has three tiers of huge stone arches.

Fig. 6-3. This dam near Lethbridge, Alberta, stores water for irrigating crop land.

DEMONSTRATION

Get two lamp chimneys or glass tubes of large diameter. Tie a piece of porous cloth around the end of each. Fill one with surface soil from a forest and the other with ordinary surface soil. Suspend each tube over a beaker of its own. Pour the same amount of water into the soil in each tube and let them stand for a few minutes. Which soil absorbs more water? How does the soil of forests help to conserve water?

Forested areas give a steadier water supply than areas without trees. For this reason we should take care of our remaining forests. We should also encourage reforestation in those areas where lumbering or forest fires have removed the natural cover of trees from the soil.

Dissolved air and minerals give water its taste. Water usually has a taste due to the presence of dissolved air and minerals in it.

DEMONSTRATION

Pour some water into a glass and let it stand in a warm place. Do bubbles collect on the inside of the glass? What are they? Where do they come from? Boil some water. Look for the tiny air bubbles as they rise just before the water begins to boil. Taste the boiled water after it has cooled. How does it taste?

Fill a narrow-mouthed bottle nearly full of water. Connect the mouth of the bottle to an exhaust pump and remove the air above the water. Result?

Water generally contains a good deal of air in solution. Watch some water as it begins to boil. The first tiny bubbles are air bubbles. These expand when heated and rise to the top. The flat taste of boiled water is largely due to a lack of air. You can restore the taste by pouring water back and forth from glass to glass. This mixes air with the water again. The process is called *aeration* (ay-er-*ay*-shun).

REVIEW QUESTIONS

1. What is the water cycle? **2.** From what different sources can we get water? **3.** How do forests help maintain a supply of pure water? **4.** What is the source of your water supply? **5.** What gives water its taste? **6.** How is a reserve supply of water maintained in your community? **7.** What two experiments may be performed to prove that water has dissolved air in it? **8.** What method may be used to remove dissolved air from water? **9.** Which source of water supply is more likely to be pure? Why? **10.** Explain the changes which occur in Fig. 6-1.

B How is water distributed from its sources to the places where it is used?

The method used to get water depends on the nature and location of the supply. Cities, towns, and villages can use four methods of supplying water for their needs: (1) the gravity system; (2) the pumping system; (3) a combination of pumping and gravity; and (4) artesian wells.

The *gravity system* depends on the force of gravity to carry the water from its source to the city using it. The

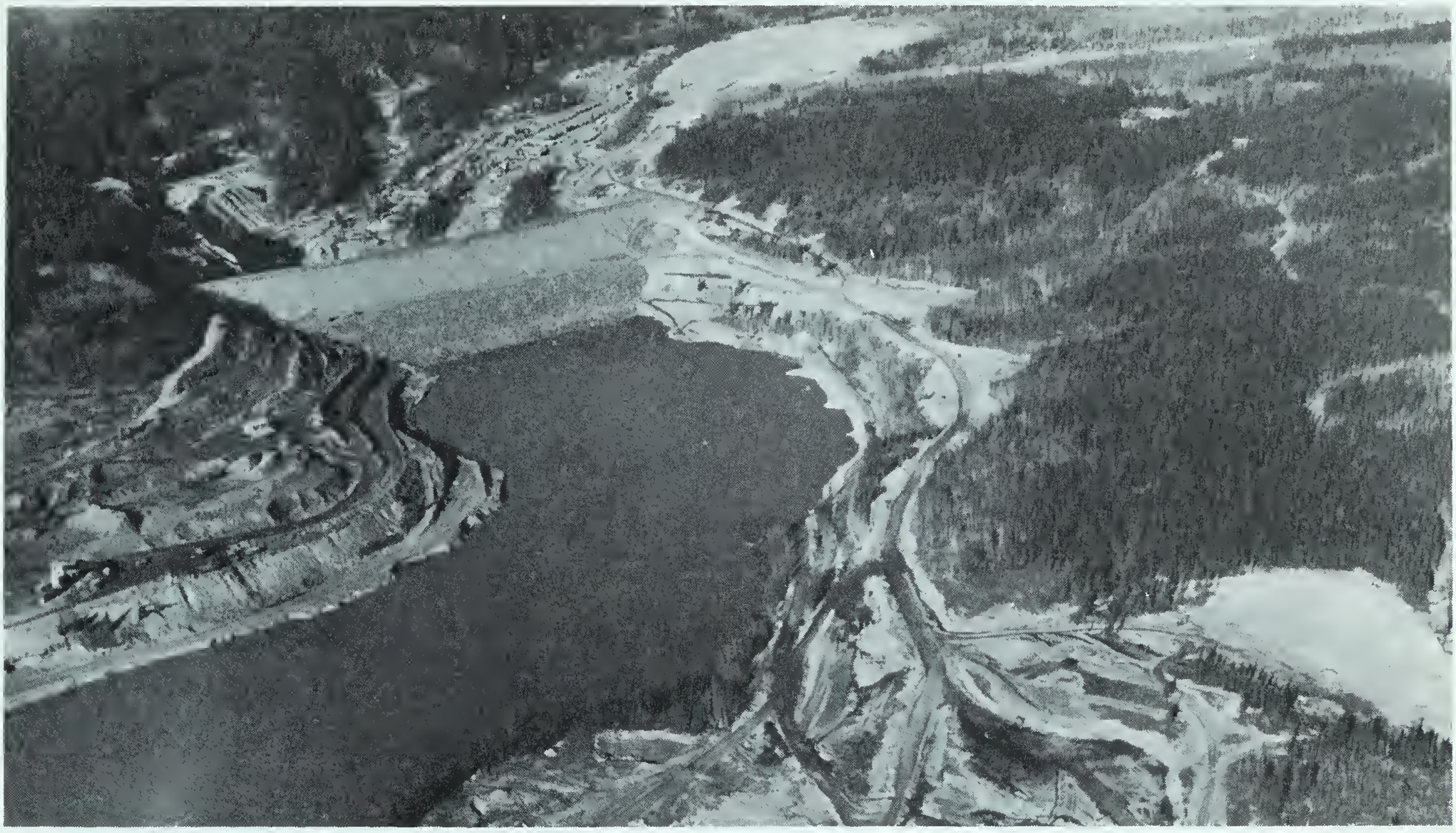


Fig. 6-4. This dam was built to prevent a chain of mountain lakes from draining eastward. The force of gravity then carries the water west to Kemano, British Columbia.

source must be higher than the city. In using this system, the water is piped directly from the reservoir in the mountains to the city (see Fig. 6-5). Cities in British Columbia, which are located in the valleys at the foot of the Rocky Mountains, draw their water from mountain lakes and rivers. Sometimes water is piped from mountain reservoirs many miles away.

Cities on rivers or lakes where there is no nearby elevation for reservoirs or towers use the ***pumping system.*** Usually, the water is first filtered and otherwise purified before being pumped through the mains. Many cities along the St. Lawrence, the Great Lakes, or other water systems use this method.

Toronto, Ontario, located on the north shore of Lake Ontario, gets its

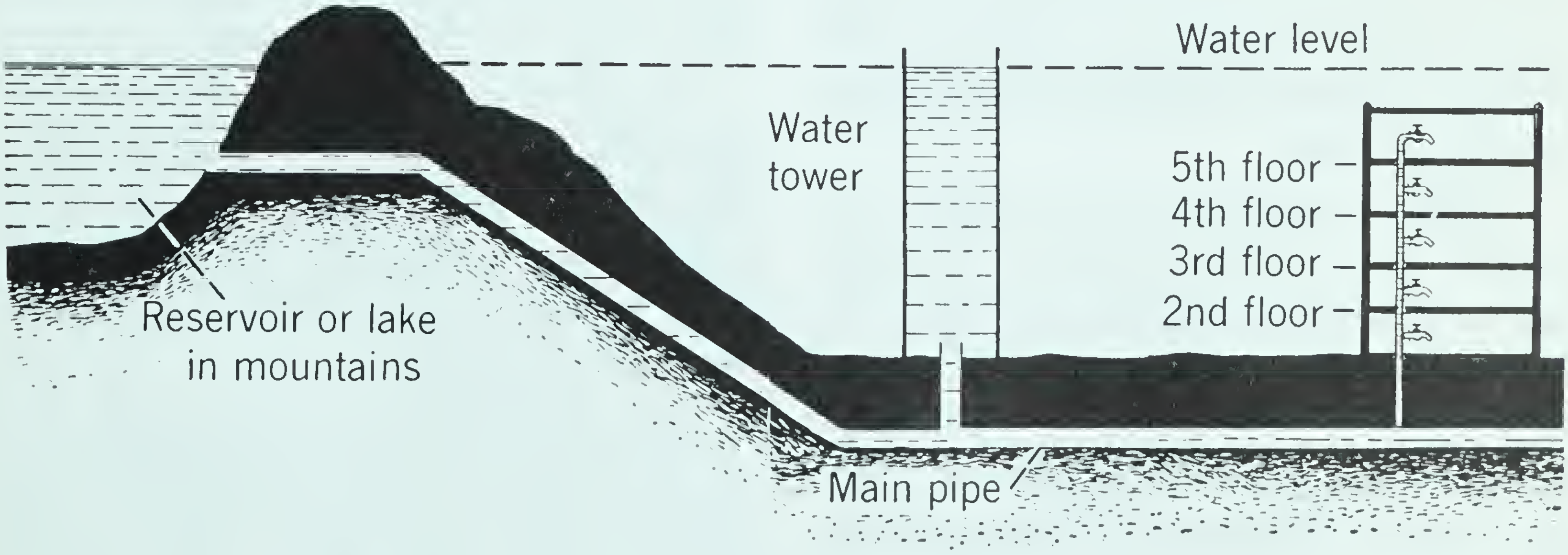


Fig. 6-5. When the source of water is at a high elevation, the force of gravity can be used to distribute the water through the main.

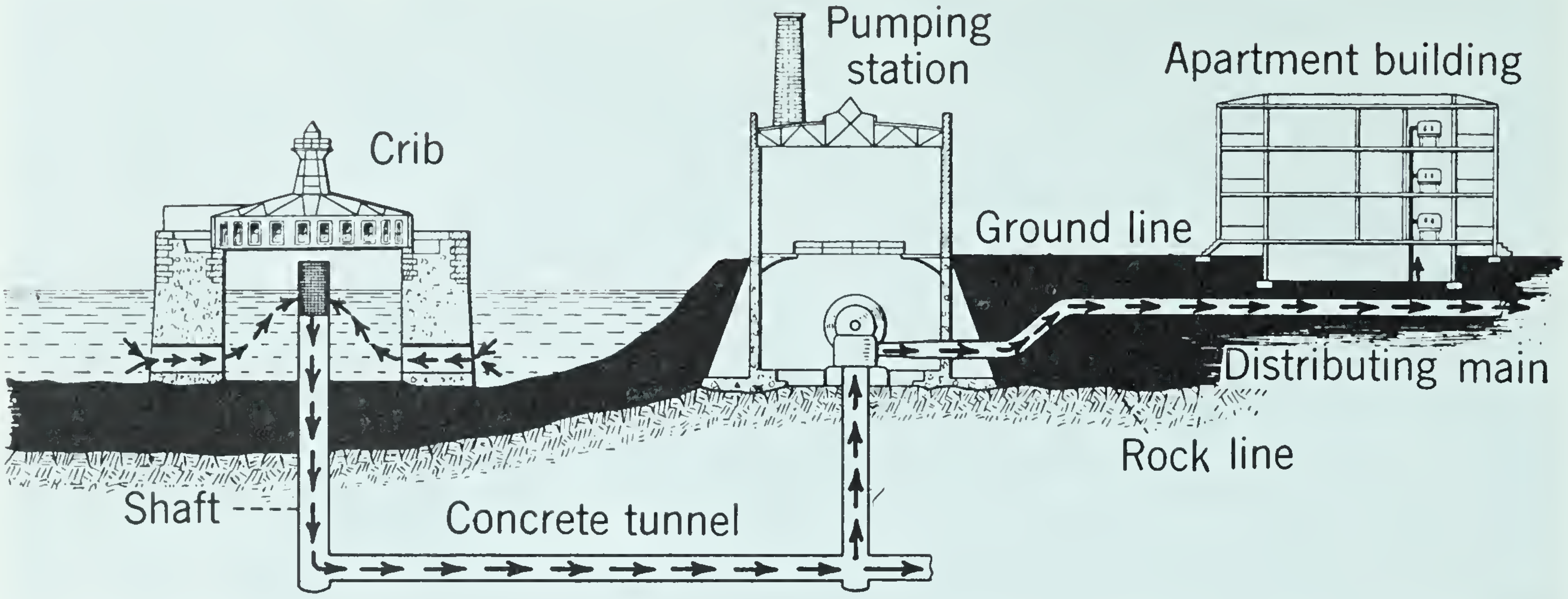


Fig. 6-6. This shows the water supply system used by Chicago located on Lake Michigan.

water from the lake. The water enters the pipes under *cribs* which are located in deep water far from the shore (see Fig. 6-6).

These pipes lead to a pumping station where the water is purified and sent under pressure to the city mains.

The *combination systems* are found in parts of the country where it is hilly enough for the use of elevated storage reservoirs or towers. The water is pumped from rivers or lakes into these structures. Then under pressure of gravity it runs directly into the mains and from them into buildings. In some cases the water is brought to a reservoir by the force of gravity and from there is pumped through the mains with enough pressure to reach the buildings where it is used.

Artesian wells can only be drilled in certain areas. They depend on deep layers of porous rock that lie between layers of non-porous rock. To get a flowing well, the source of water in the porous layer must be higher than the area where the well is being drilled. If an artesian well does not flow, the water must be pumped from it in the same way as from a surface well. Artesian wells supply small towns and villages and houses with all the pure water necessary for their needs if a pumping system is used.

PUPIL ACTIVITY

How does your community get its water? Make a diagram to illustrate how the water is distributed.

Water supplies are stored in reservoirs or towers. The smaller towns and cities usually store water in towers. This method is satisfactory because the amount of water used daily is not very large. Also buildings are not so tall that they need high pressure.

In big cities with tall buildings, this system is not practical because it would require a large number of towers. It would also be difficult to build towers high enough to get sufficient pressure for tall buildings.

Some cities have water reservoirs at high altitudes. Many communities have a reserve supply of water to be used in case of large fires. This insures enough water for fire-fighting, even

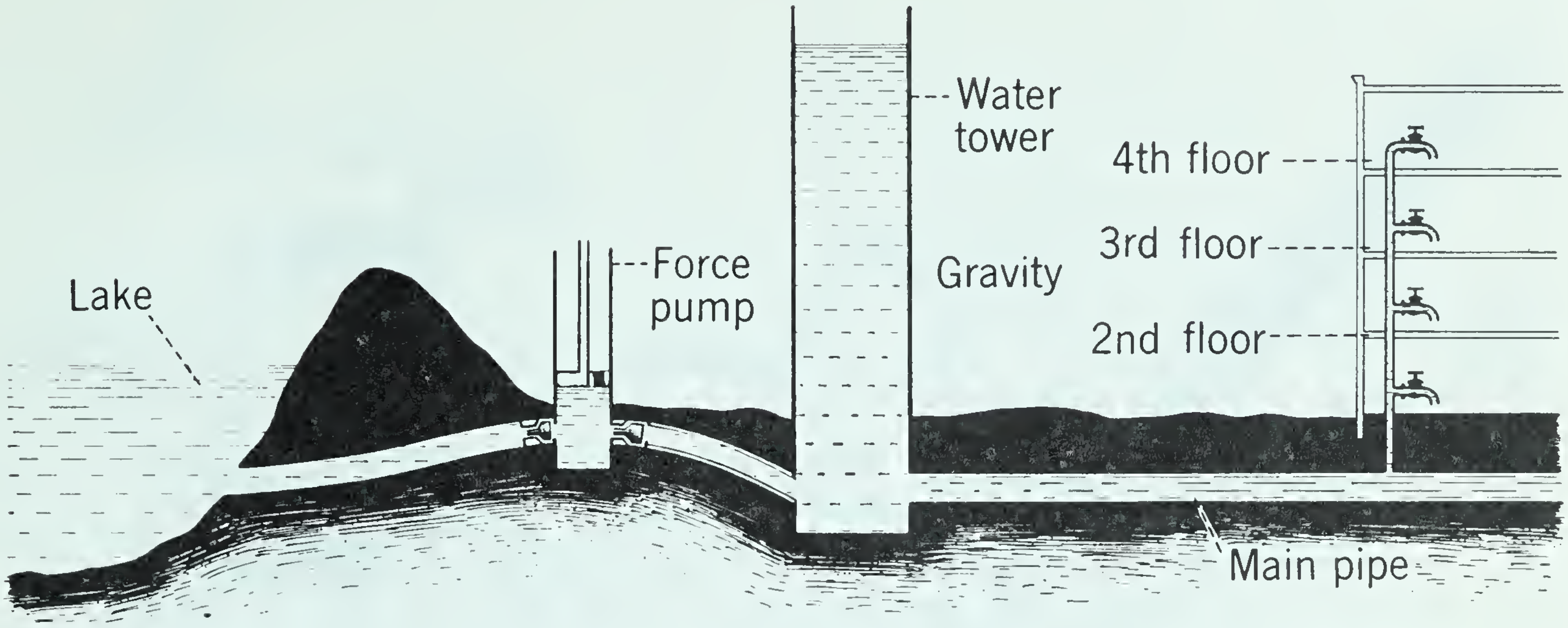


Fig. 6-7. Here a water tower is used to help regulate the flow and pressure of the water.

though large quantities of water may be drawn for other purposes at the same time.

Water reaches its own level. If two tanks or vessels of different sizes are connected by a pipe, what will be the level of water in each? Will it be higher or lower in the larger tank, or will the water be at the same level in both?

DEMONSTRATION

Connect two funnels of different diameters with a piece of rubber tubing as in Fig. 6-8. Pour water into one funnel. Continue pouring until you can see water in the second funnel. What is the water level in the two funnels? Raise one of the funnels. Result?

Water in two connected vessels will reach the same level. This is true for any number of connected vessels. The water in a tower will flow to any building which is at a lower level, but will not reach a higher level. Why?

Compressed air can be used to force water through pipes. In some cities, pumps force water into closed tanks filled with air. As the water flows into the tank, it compresses the air. (Fig. 6-9.) This compressed air can then be used to force water through the mains, or pipes. You can get any desired pressure in this way. In case of fire, more water could be pumped into the tanks to increase the pressure.

You can also put pressure on water in a partly filled closed tank by pumping air into the tank. (Fig. 6-9.) As more air is pumped in, the pressure increases. Some houses not connected to a city water system have their own pressure system. They use an electric

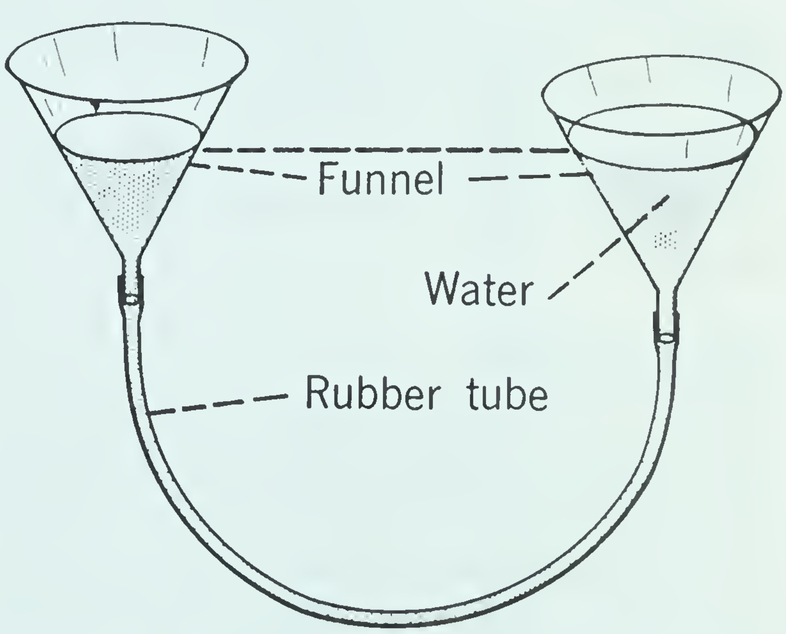


Fig. 6-8. When two vessels are connected, water reaches the same level in both.

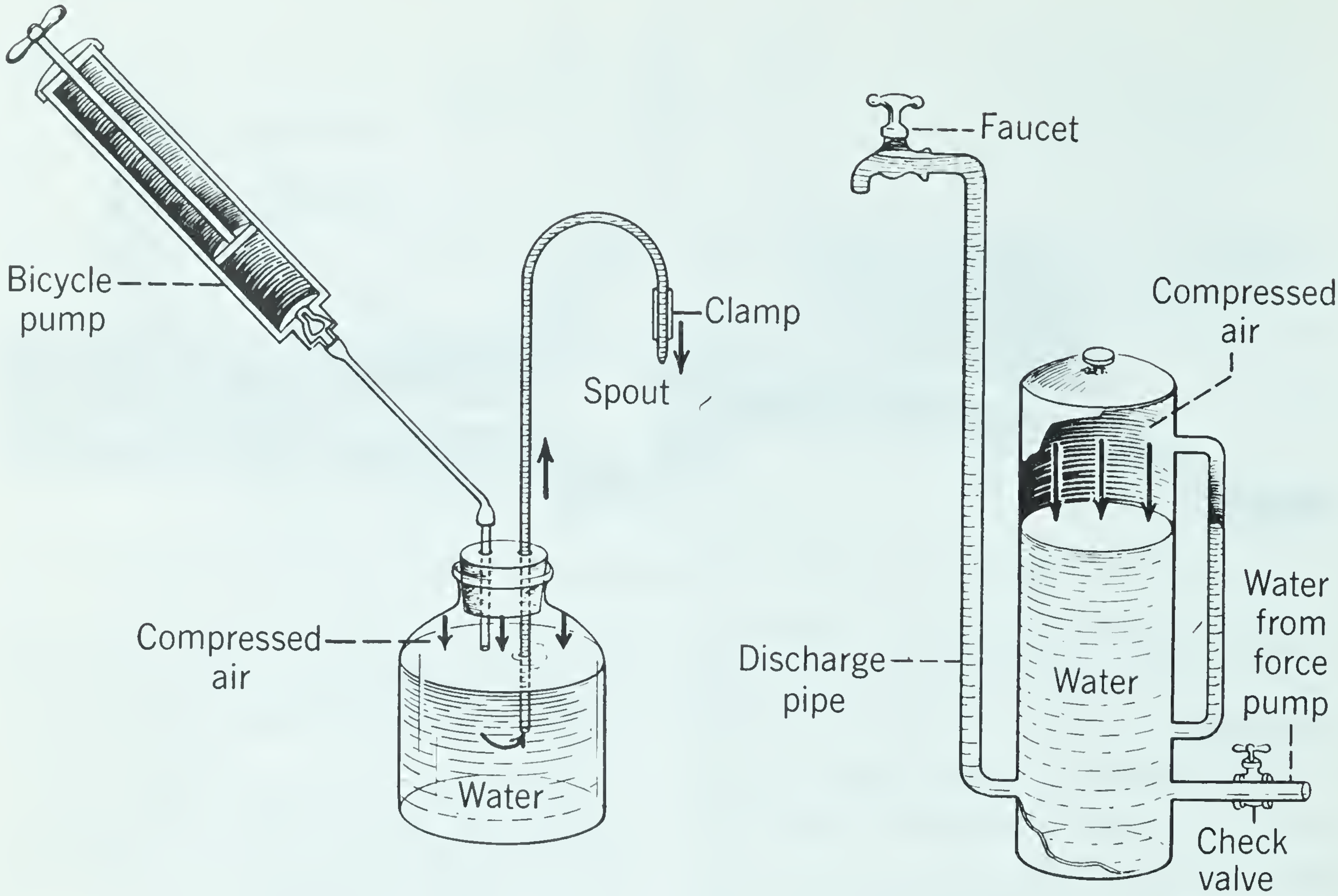


Fig. 6-9. As you can see in the above diagrams, compressed air can be used to force water to any desired location.

motor to run a pump. This forces water into a tank containing some air. The water compresses the air. Then the compressed air is used to furnish pressure to force the water through the pipes in the house.

Pressure in water varies with the depth. You have probably noticed that when you dive into deep water the pressure increases with the depth. The deeper the water the greater the pressure.

PUPIL ACTIVITY

Find a tall tin can. Punch holes in its side two inches apart in a vertical line as shown in Fig. 6-10. Punch the first hole one inch from the bottom and the second two inches above the first. A third hole should be punched two inches above the second. Then fill the can with water. Keep it filled and watch where the water flows out with the greatest force. Where is the pressure of water the greatest? Why?

By *pressure* we mean the force of a substance against a unit of area. The unit of area may be a square inch, square foot, or square yard. We usually speak of water pressure as so many pounds per square inch.

When a dam, reservoir, or water tower is built, engineers must determine the thickness and strength of the walls. They know that one cubic foot of water weighs 62.4 pounds. Pressure at the bottom of a column of water will be 62.4 pounds per square foot times the height of the column of water in feet.

If you fill a container which is one

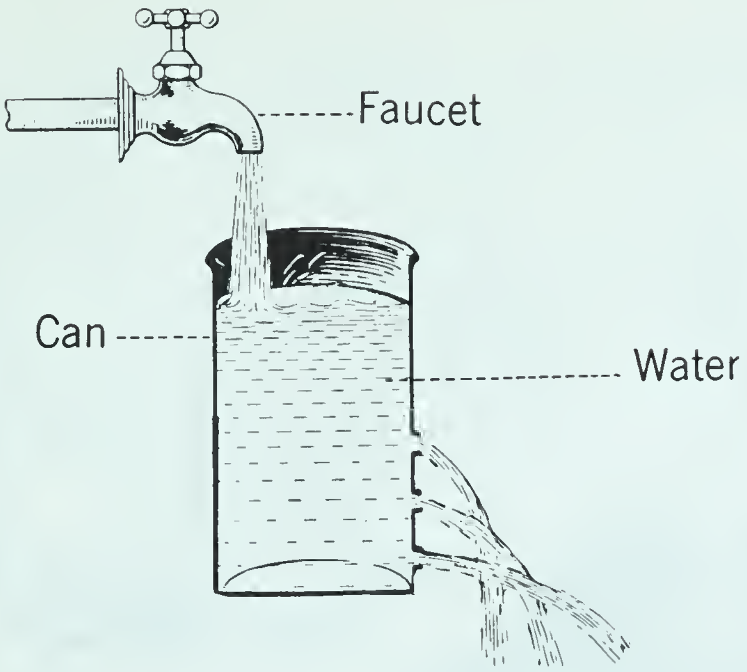


Fig. 6-10. As the depth of water increases, so does the pressure.

foot long, one foot wide, and one foot deep with water, the volume of the water will be *one cubic foot*. The weight of this volume of water will be 62.4 pounds. Or the pressure will be 62.4 pounds per square foot on the bottom of the container of water. There are, as you will recall, 144 square inches in one square foot. Thus the pressure per square inch at the bottom will be 62.4 ÷ 144, or .43 pounds per square inch. This means there is a pressure of .43 pounds per square inch at a depth of one foot in water. Fig. 6-11 will help you to understand this.

A column of water ten feet high will give a pressure of 4.3 lb. per square inch (10 × .43 = 4.3). For a depth of 100 feet, the pressure will be 43 lb. per square inch (100 × .43 = 43). What will be the pressure in a water tower which is 150 feet high?

In a dam, reservoir, or tower, the pressure on each square foot of the sides next to the bottom will be almost as much as the pressure on the bottom. The pressure on the sides half way up will be half the pressure at the bottom. Therefore, as the depth of the water varies, the pressure will also vary.

Pressure is independent of the size and shape of a container. Knowing what we mean by water pressure, we can now ask this question. Why do some towns and cities build water towers with small pipes leading to the upper part of the towers? Other towns

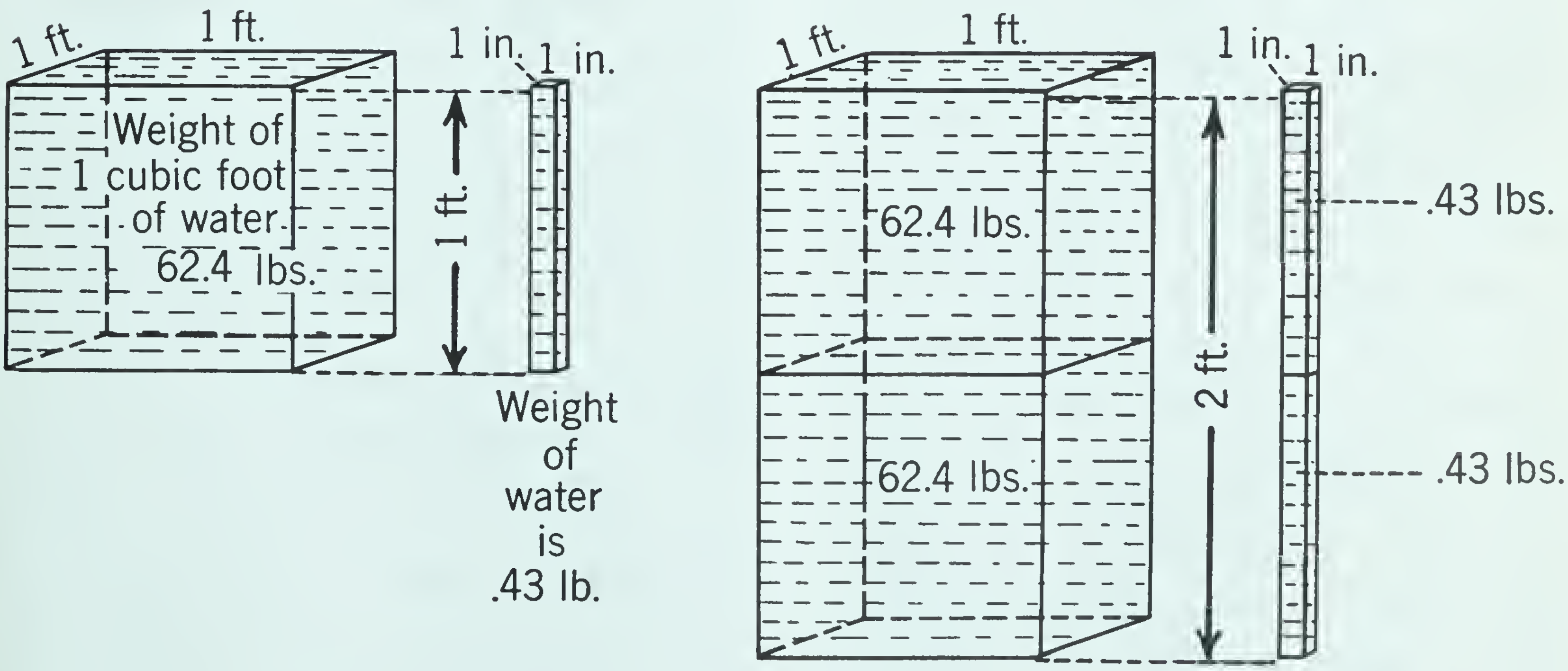


Fig. 6-11. The pressure in water per square inch for each foot of depth is .43 pound.

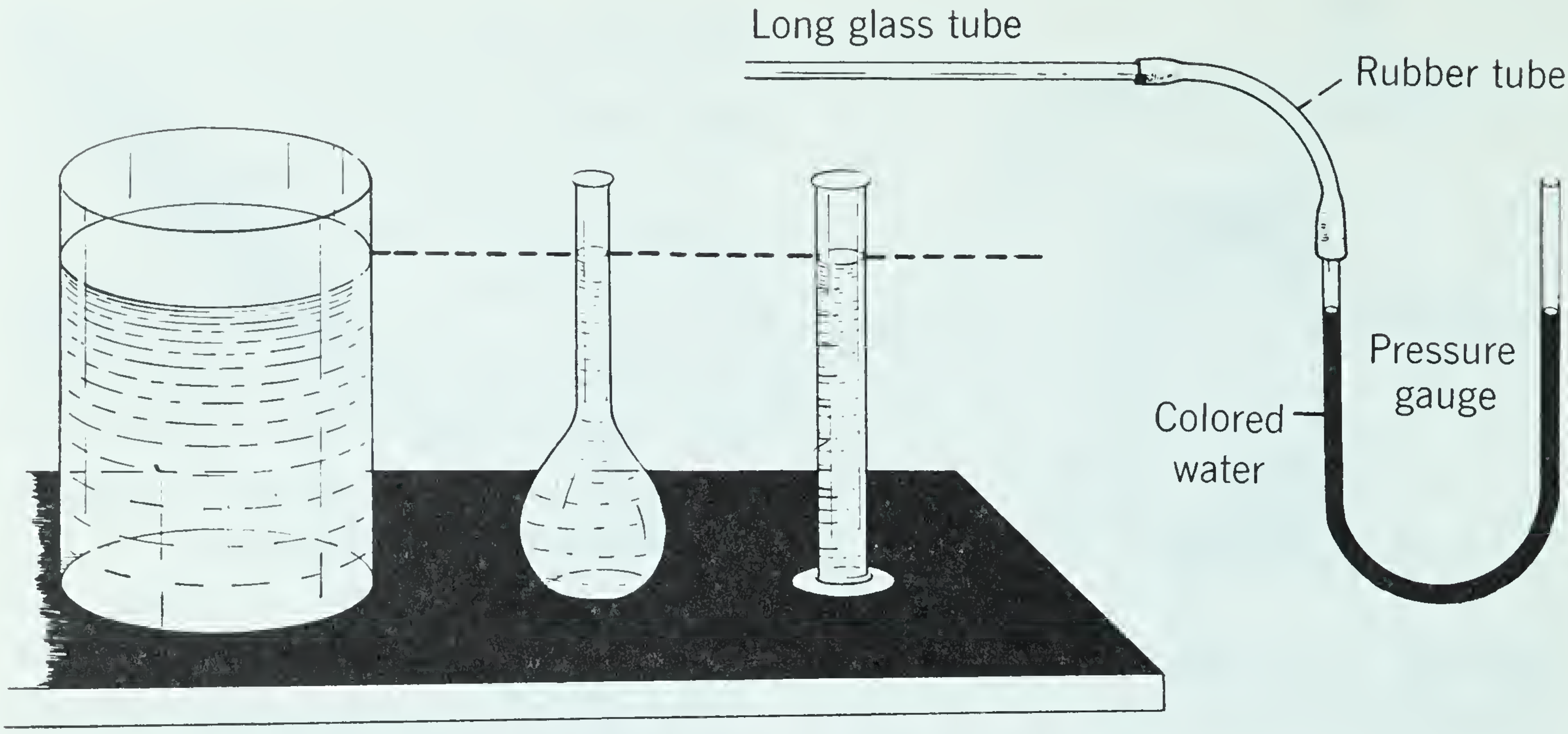


Fig. 6-12. As this diagram shows, the shape of the container or the volume of water does not affect the pressure in water.

build their towers vertically from the ground up.

DEMONSTRATION

Connect a long glass tube to a piece of rubber tubing. Attach the rubber tube to a simple pressure gauge as shown in Fig. 6-12. Pour some colored water into the pressure gauge. Find a few containers of various shapes and sizes. Fill them with water to the same depth. Now push the long glass tube to the bottom of the water in each container. What happens in the pressure gauge? Are the results the same in the different containers? Conclusion?

These experiments show that the pressure in water is not affected either by the shape of the container or by the volume of water. Therefore, the important factor in building a water tower is its height.

If pressure is desired, it is cheaper to build a high tower by building a small tank at the top of steel supports than to build a large tank from the ground up. A small tank at the top of a tower gives satisfactory pressure but not a large volume of water. For this reason, this kind of tower is used for single buildings or a small town. But it does not hold enough water for large cities.

REVIEW QUESTIONS

1. Under what conditions is the gravity system used for getting a water supply? The pump system? The combination system? Artesian wells? **2.** What determines the pressure in water? **3.** Why is it permissible to have a water tank weaker at the top than at the bottom? **4.** How is the pressure affected by the shape of a container? By the volume of a container? **5.** In what ways may pressure be developed to force water through the pipes of a city water system? **6.** What method is used to supply your community with water? **7.** Why does a water gauge give the level of water in a boiler? **8.** How high a water tower is needed to develop a pressure of 43 pounds per square inch at the bottom? **9.** What is the meaning of force in water? Of pres-

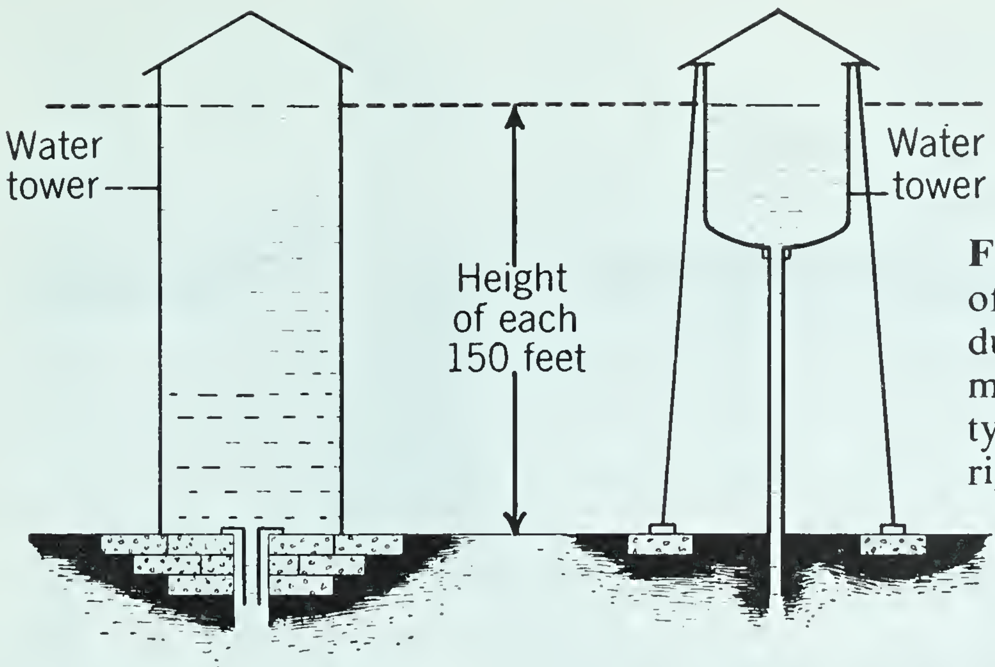


Fig. 6-13. Since both water towers are of the same height, the pressure produced in both is the same. Why do many towns and industries use the type of water tower shown at the right?

sure? **10.** What are the advantages of the gravity system over the pumping system in supplying a city with water? What are the disadvantages? **11.** What is the real meaning of the expression "water reaches it own level"?

C How can drinking water be kept pure?

Organic waste matter makes water impure. The word *organic* means something coming from living things. Therefore, when we say organic waste matter, we refer to all matter which comes from living things, both plant and animal.

Even the clearest water may contain disease germs, especially if it is near privies, sewers, or cesspools. The germs of many diseases such as cholera, typhoid, diarrhea, and dysentery often exist in it, or are carried by water. It is of vital importance that our drinking water be kept free of germs.

We call these germs ***bacteria*** (bac-*tih*-ree-ah). These bacteria are the smallest and simplest plants known to science. They are so small that you can see them only with a microscope. There are many kinds of bacteria, some harmful, some beneficial.

There are many ways in which bacteria can get into water and thus into our digestive tracts. The most important are: (1) wastes from human beings and animals; (2) garbage; and (3) parts or entire bodies of decaying plants and animals.

Shallow wells are always possible sources of danger because rain may wash filth into them. Cesspools, kitchen drains, and outbuildings can pollute water in wells if they are too near the wells.

PUPIL ACTIVITY

Examine the structure and location of a house well. Look at Fig. 6-14. How is it made? How deep is it? Do heavy rains affect the height of the water? Can surface water drain into it? Are the sides stoned or cemented? Can drainage from a barnyard reach it? Do you consider the water safe to drink?

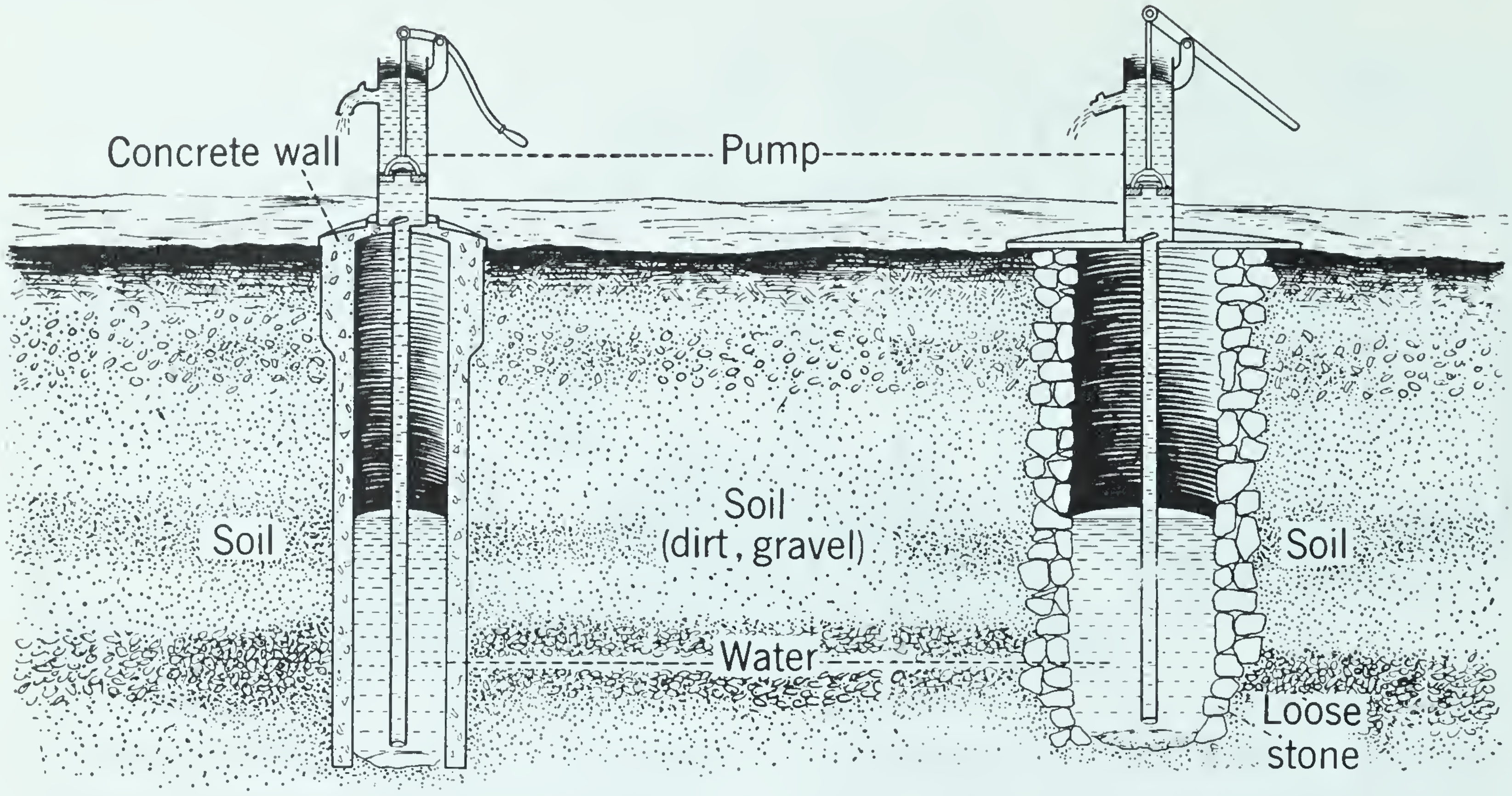


Fig. 6-14. The walls of wells should be built of solid materials to prevent surface filth from seeping into them.

Some houses use a well as the source of water but have no sewage system. In that case, a cesspool is usually the way to dispose of sewage.

A *cesspool* is merely a large hole in the ground about 12 feet deep with a bottom filled with stones or coarse gravel. Its walls should be made of concrete, stone, or brick and it should be closed at the top. The solid materials in sewage are changed to liquid form by the bacteria in the cesspool. The liquid portions gradually seep down into the soil.

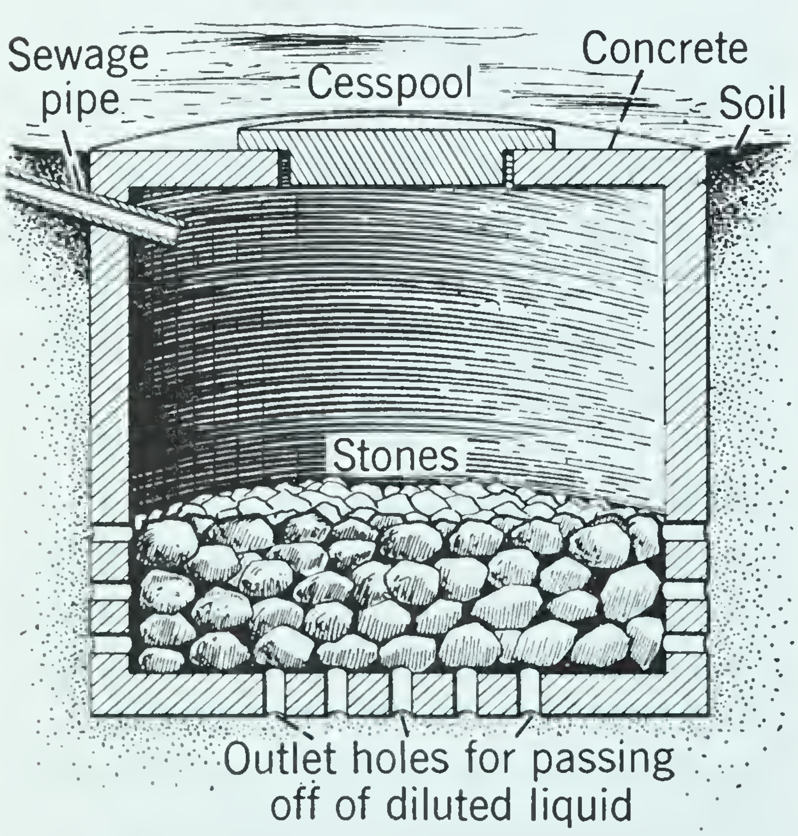


Fig. 6-15. What is the disadvantage of the cesspool as a method of sewage disposal?

Cesspools should be dug at least 50 feet from any well and the drainage should be away from the well. A cesspool is not the best method of sewage disposal because it may permit disease bacteria to escape into the soil. See Fig. 6-15.

Septic tanks provide a much safer method of disposing of sewage. They are made of concrete, steel, or tile and are divided into three compartments. Sewage from the house flows into the first compartment where solids settle to the bottom. The sewage is decayed by harmless bacteria in the several compartments and finally escapes as a colorless, odorless fluid. It can pass

into the soil, or into containers to be used as fertilizer for the garden.

Most towns and cities have a sewage disposal plant. It receives the sewage in sewer pipes from all the buildings in town. Some systems use very large septic tanks combined with filters of sand and gravel. Others use mechanical methods to stir up the sewage for faster decay of organic matter.

It is the practice in larger communities to test the water supply often. Thus they can detect the presence of disease germs before they become too numerous. A poison gas called *chlorine* (*klor*-ēen) is added to water in many towns. A little chlorine will kill all disease germs in water.

If you live in a rural area, you can have your water supply checked by the state or local board of health.

DEMONSTRATION

Add a few drops of sulfuric acid to the water to be tested. To this add a small amount of potassium permanganate until the water is colored. Boil. If the water keeps its color, there is no organic matter present, but if the water turns brown or colorless, organic matter is present.

Heat a little of the water to be tested in a corked flask. *Do not boil.* Smell the contents. Pure water is free from odor.

Bacteria in water can be destroyed in several ways. One way is by *boiling.* This does not destroy all bacteria but it gets rid of the most dangerous ones. It is not practical to purify large amounts of water by boiling. Why?

A second way is *chlorination.* Most big cities purify their water by letting chlorine gas flow into it. Chlorine will destroy disease germs. Too much will give the water an unpleasant taste.

A third way is to *spray the water into the air.* Even clear sparkling water may not be safe. When water is sprayed into the air, the disease germs are destroyed both by the oxygen in the air and by exposure to sunlight.

REVIEW QUESTIONS

1. What types of impurities are frequently found in water? **2.** How do these impurities get into the water? **3.** Why is a septic tank a better method of sewage

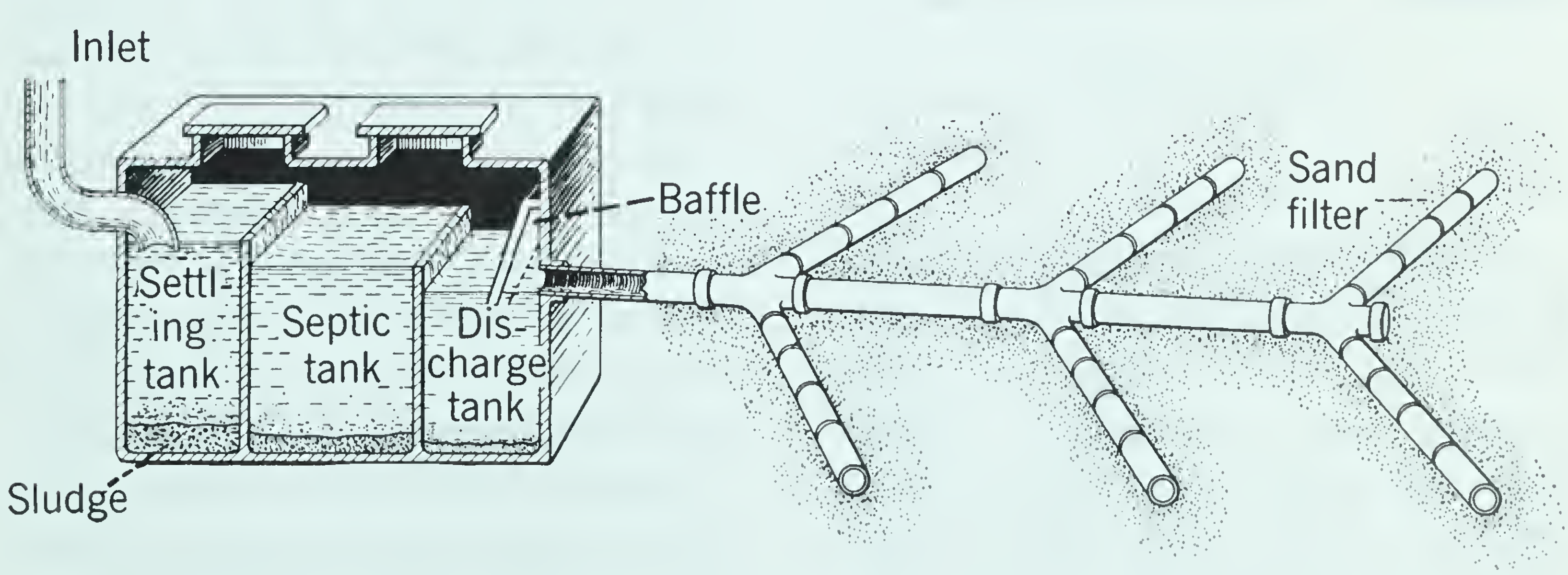


Fig. 6-16. Why is the septic tank a much safer method of sewage disposal?

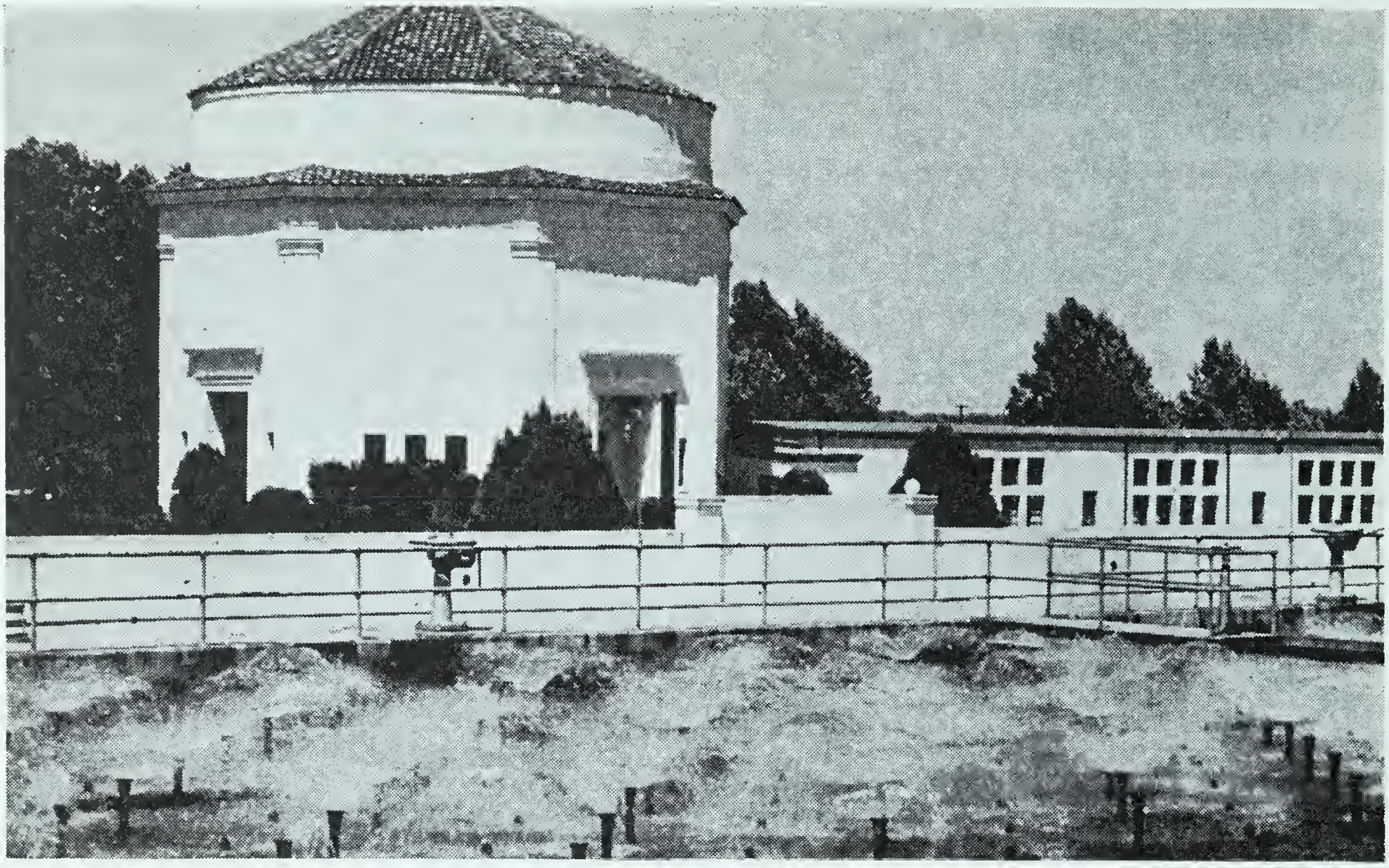


Fig. 6-17. Spraying water in the air and sunshine helps kill harmful germs and improves the taste.

disposal than the cesspool? **4.** What methods are used by cities to dispose of their sewage? **5.** What is the test for organic matter in water? **6.** How are bacteria in water destroyed?

D How are solid materials removed from water?

Distilling removes dissolved matter in water and makes it chemically pure. Water from deep springs and wells, running water in mountain regions, and rain water are usually safe to drink. However, these may contain dissolved mineral salts. Rain water and distilled water are nearly free of them. Chemists and druggists sometimes require water that has no dissolved minerals in it.

Nature's ways of purifying water are: (1) *filtering;* and (2) *distilling.* Water is filtered as it seeps through soil and gravel or sand. This removes bacteria and organic matter. However, as water seeps down it dissolves minerals from the soil and rocks through which it passes.

Nature distills water by the heat of the sun which evaporates it from streams, lakes, and oceans. As you learned in Unit 5, this water vapor is pushed up to cooler regions where it condenses and falls as rain or snow.

Chemical laboratories distill water by using special apparatus, as you can see in the following Demonstration.

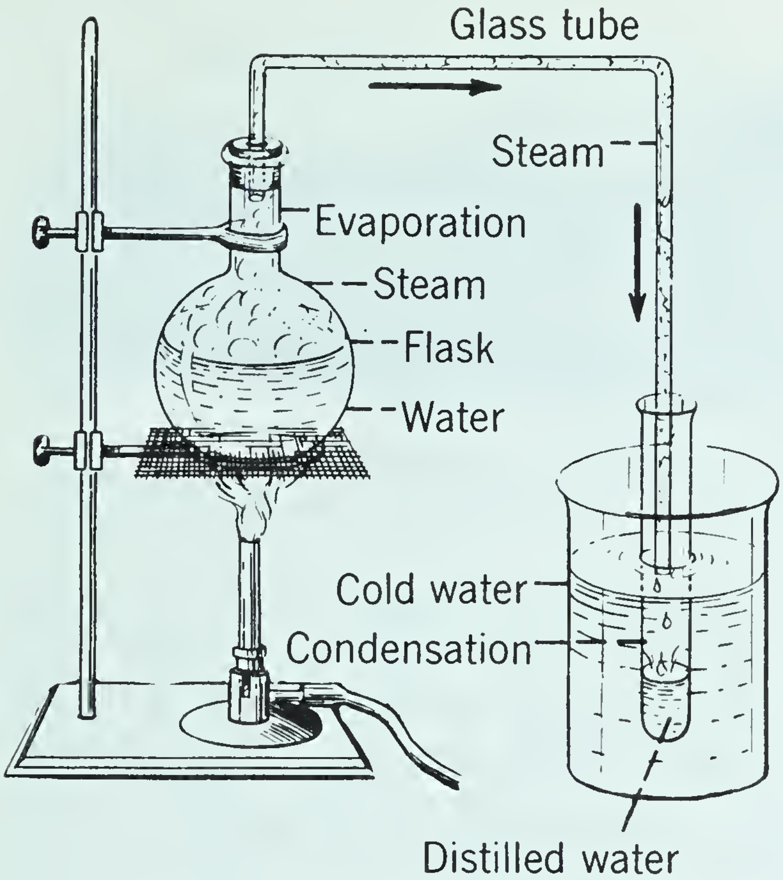


Fig. 6-18. In distillation, water is evaporated by heating and condensed by cooling. How does distillation purify water?

DEMONSTRATION

Dissolve a spoonful of salt in a small amount of water. Entirely evaporate the water by boiling it in an evaporating dish. Result? Evaporate rain water or distilled water in the same way. Result? What is the cause of a deposit in teakettles? What is "boiler scale"? Why are the mineral salts left as a deposit?

Arrange the distilling apparatus as shown in the diagram in Fig. 6-18. Put a quantity of muddy, salty, or inky water in the flask. Put the end of the delivery tube in a test tube surrounded by cold water. Heat the flask slowly until an inch or so of water condenses in the test tube. How does it taste? Is it pure? Why is rain water so pure? How does nature distill water? What makes the ocean so salty?

When you prepare water in this way, it is called ***distilled water.*** Chemists, druggists, and scientists use it in their work because it is chemically pure. Tap water might spoil chemical work or medicine because it contains dissolved mineral salts.

When you boil water, it changes to a vapor. The dissolved minerals do not vaporize at this temperature. The steam formed passes off and condenses as it cools. If all the water is boiled away, the dissolved mineral salts remain.

In recent years research scientists have developed chemicals that will remove all dissolved minerals from water. Thus, it is now possible to obtain chemically pure water without distillation.

Filtering removes sediment from water. In all bodies of water there is some sediment. It tends to make the water cloudy and provides material for the growth of bacteria. Sediment can be removed by ***filtering.***

In the laboratory you can make a filter by filling a large funnel with clean sand or powdered charcoal. Or, you can use a filter paper (see Fig. 6-19).

DEMONSTRATION

Fill a large funnel with clean fine sand. Pour some muddy water into the sand. Is the water that comes through the sand clear? If not, filter it a second time. Result? Now put a plug of glass wool or cotton into the funnel. Then fill the funnel with powdered charcoal. Compare the powdered charcoal with sand as a filtering agent.

Fold a piece of filter paper and fit it into the funnel. Pour some muddy water in the filter paper. Result? Repeat the experiment by adding some salt to the

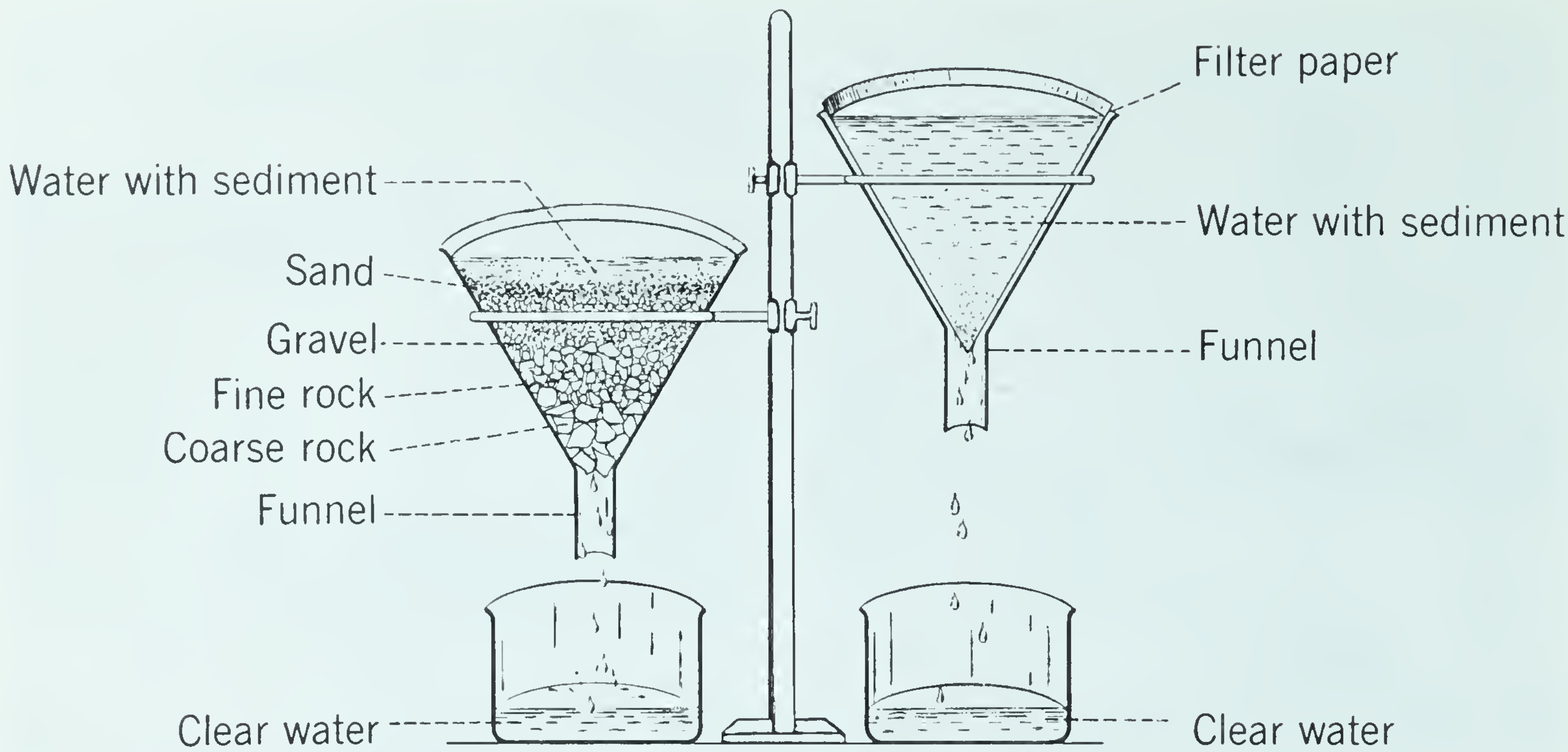


Fig. 6-19. All water contains some sediment. Filtering removes this sediment.

muddy water. Taste the water that flows through the paper. Result? What did the filter paper remove?

In a city water system the sediment may be removed by passing the water through filter beds of sand and charcoal. In time, a thick layer of sediment forms. Then it is necessary to wash the filter by reversing the flow of water. Sometimes more of the filtering element must be added to replace what is lost in the washing process.

The settling of sediment may be speeded up by the use of chemicals which form a jellylike mass. As this settles to the bottom it carries the sediment down with it. This process of settling is called *coagulation* (ko-ag-yew-*lay*-shun).

DEMONSTRATION

Hang a small bag of powdered alum and slaked lime in a glass of slightly muddy water for a few minutes. Result? As a control, fill a similar glass with the same sort of muddy water but leave out the alum and lime. What is the use of the control? Result of the control? How was the sediment removed?

The chemical tends to collect the small particles into larger ones. They sink to the bottom and carry with them most of the sediment in the water.

Water is called "hard" if it contains certain dissolved minerals. These minerals are in the form of calcium or magnesium salts. Water can be softened by removing these dissolved minerals. This can be done chemically.

DEMONSTRATION

Get some "limewater." Limewater is really a dilute solution of calcium hydroxide. To a test tube half-filled with this solution, add ten drops of soap solution. Now shake the test tube vigorously and let it stand for a minute or two. What change has taken place? Has any scum formed? To a second portion of limewater add a small amount of borax, or washing soda, and ten drops of soap

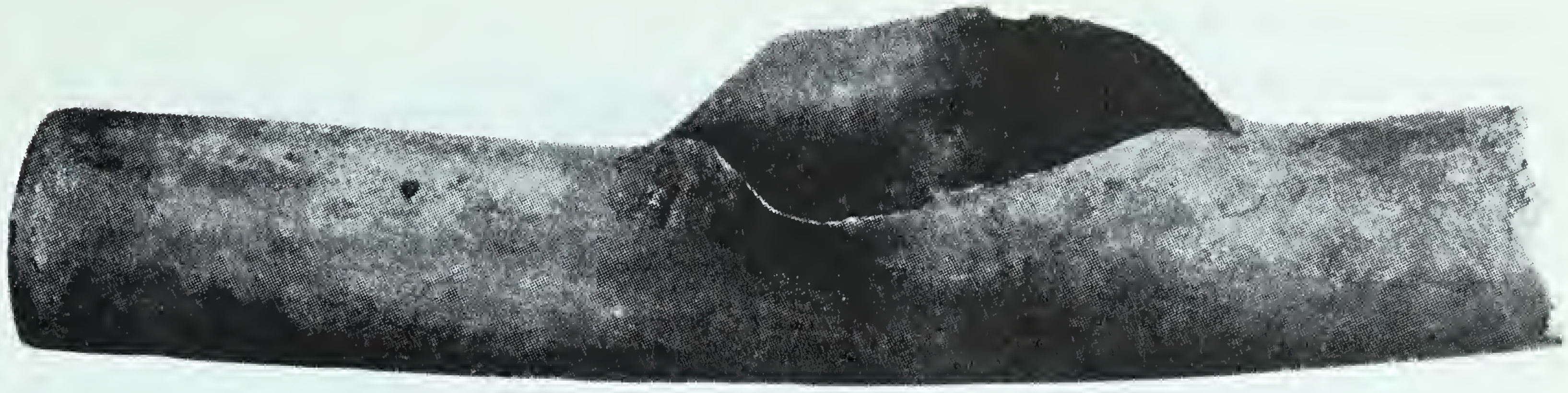


Fig. 6-20. The bursting of this boiler tube was caused by the accumulation of minerals, called boiler scale, from the hard water used in the boiler.

solution. What happens this time? Repeat, using a detergent. In a fourth test tube, put some distilled water and add ten drops of soap, but no detergent. Shake. What happens? What is the purpose of adding detergents to soaps and soap powders?

If you add soap or certain chemicals to hard water, a scum forms. This scum consists of the minerals combined with the soap. Therefore, the amount of soap used to soften water depends on the amount of dissolved minerals in the water. Hard water wastes soap.

In recent years a class of chemical compounds known as detergents have been made available to housewives.

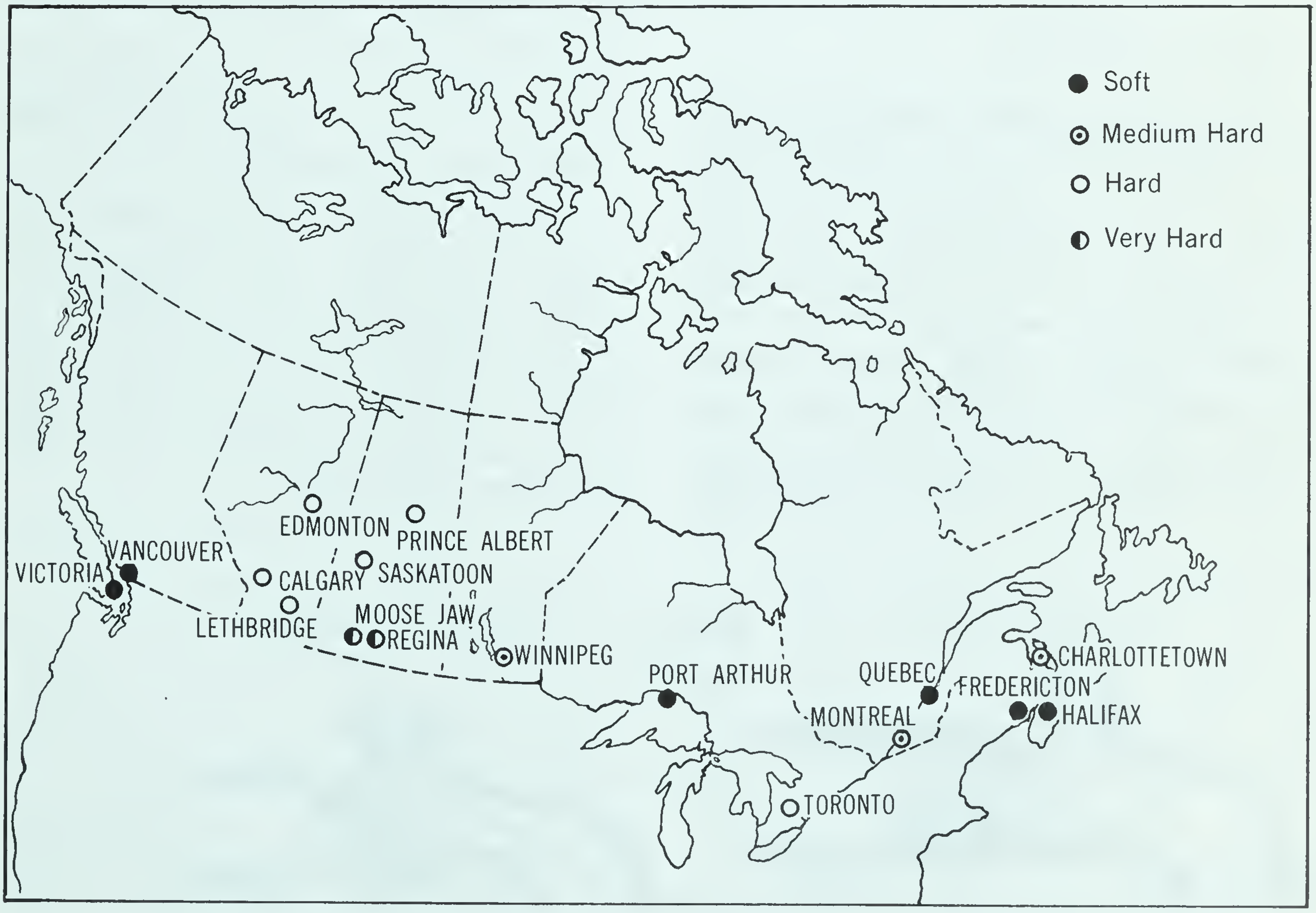


Fig. 6-21. As you can see from the above map, the degrees of hardness of water vary in different sections of the country. Does your region have hard or soft water?

These are sold under different trade names. More frequently the detergent is added to soap or soap powder and the combination is sold as a "washing powder." Detergents act like soaps but are not affected by hard water. What are the trade names of some of these products sold in stores?

Soap does not dissolve grease, oil, or dirt. In the laundry, soap breaks the grease and dirt into tiny particles and surrounds them. This removes the grease and dirt from the cloth. Water washes away these particles in the rinsing. Dry cleaning is done without water. Gasoline, benzine, or carbon tetrachloride are used to dissolve grease from clothing. No soap is required in dry cleaning.

REVIEW QUESTIONS

1. Why do we distill water? **2.** How does nature purify water? **3.** What kinds of material does filtering remove from water? **4.** What materials can you use for filters? **5.** Why must you add new material when sand and charcoal are used for filters? **6.** How is water purified by coagulation? **7.** What is hard water? **8.** How does soap remove oil and grease from clothing? **9.** What is a detergent?

E How is the flow of water controlled in the home?

The plumbing system brings water into the house and removes waste materials. The plumbing in your house includes: pipes, faucets, traps, and flushing tanks. Iron, copper, or brass pipes are used today, but brass pipes cost much more than iron and copper ones. Iron pipes are lined with zinc (galvanized) to prevent them from rusting.

The flow of water through the pipes is controlled by faucets. If possible, get a faucet and study its parts. Find out how to operate the faucet. Locate the washer. Can you replace the washer if it is worn or defective?

Traps prevent sewer gas from entering the house. Traps are parts of waste pipes bent into a U-shape so that they will always be full of water. This forms a water seal and prevents sewer gas from entering the house from the sewer pipes.

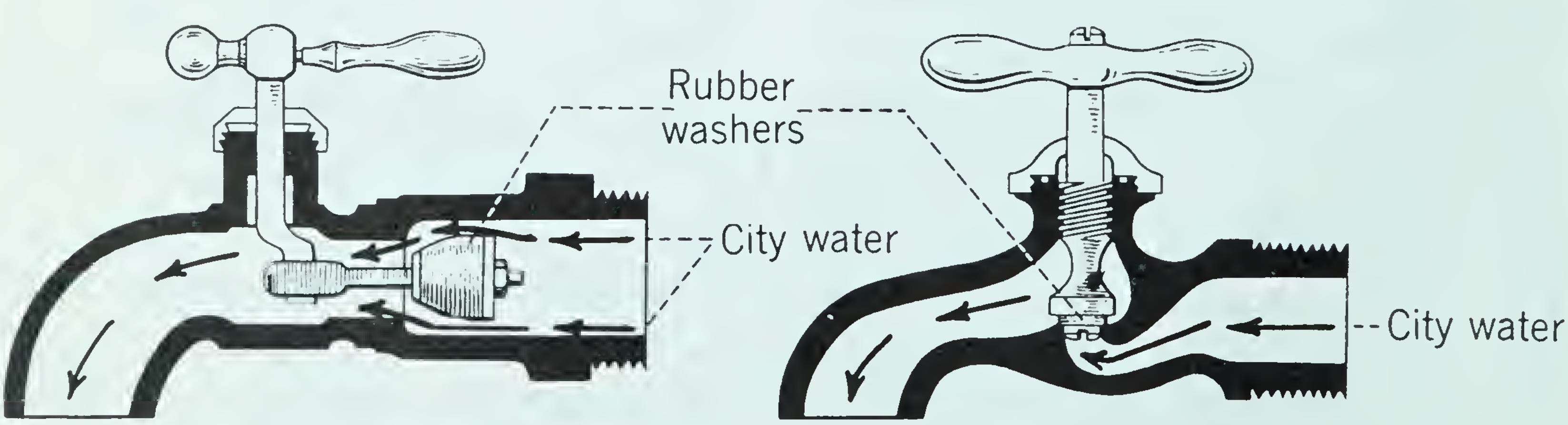


Fig. 6-22. Name the parts of a faucet and explain how it operates. How do these two types differ?

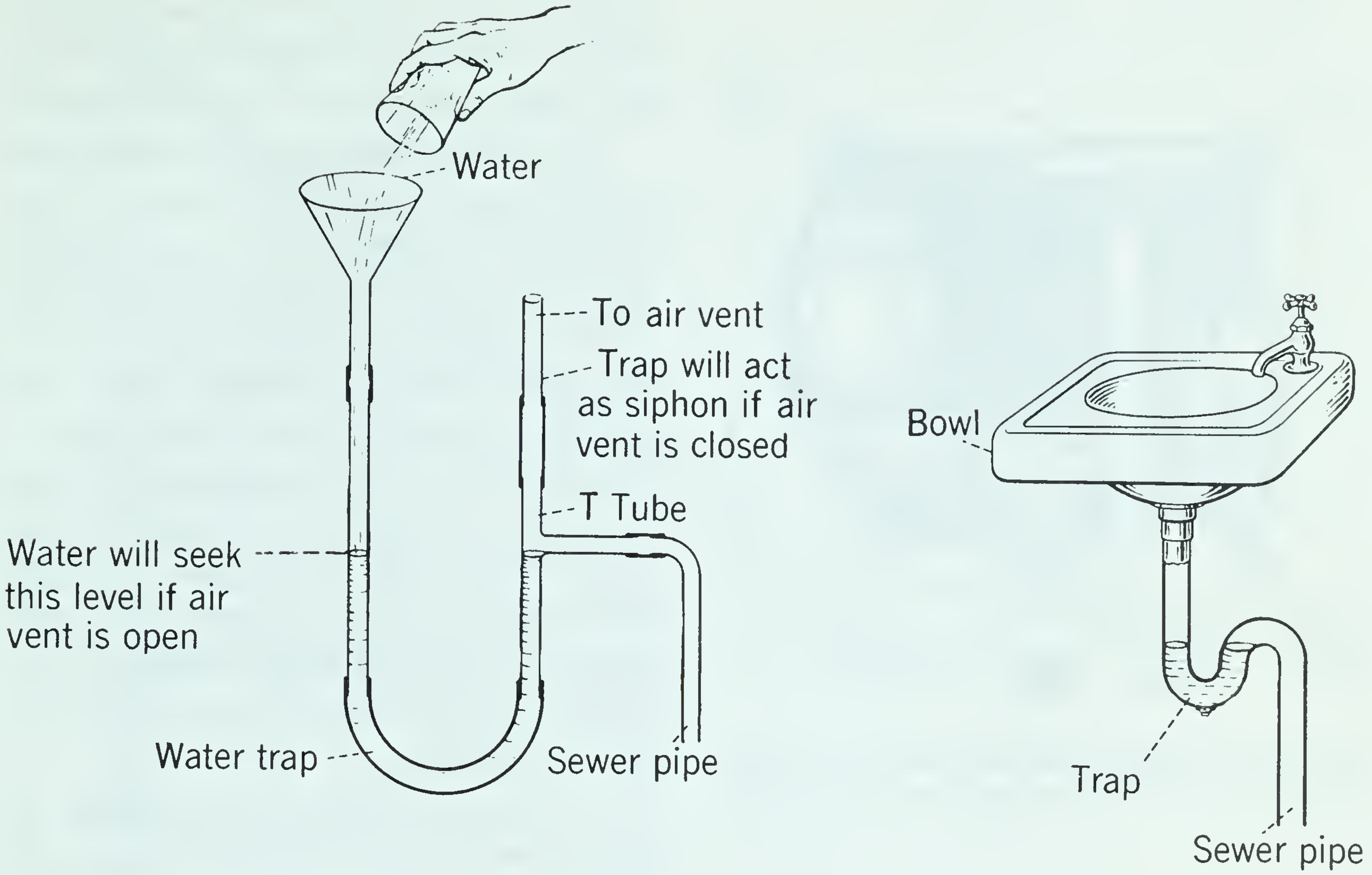


Fig. 6-23. U-shaped traps, filled with water, prevent sewer gases from entering the house.

PUPIL ACTIVITY

Examine a trap such as the one under your kitchen sink. Note the drain plug at the lower part. Put a pail under the trap and remove the plug. If there is any sediment in the trap, remove it with a wire and flush the trap. Note that the water left in the U-shaped portion or the water seal prevents the sewer gases from entering the house. Sometimes this gets clogged by refuse from the sink.

You can remove the waste by *carefully* pouring a hot-water solution of lye through the trap. Larger amounts of waste may demand a sink pump or large suction disk. The disk acts as the piston in a pump. The air pressure forces the material into the sink or through the drain pipe. If a sink pump or suction disk will not clear the pipe, use a wrench to remove the plug at the bottom. The trap can then be cleaned. If lye has been used, be careful that the liquid does not spatter. If it gets on you, wash it off promptly.

A flush tank controls the flow of water through the toilet. Most houses have them. There are many kinds of flush tanks, but they all operate on the same principle. With the aid of the drawings in Fig. 6-24 and Fig. 6-25, examine the flush tank at home. Find the large ball float. What is its purpose? Push the ball down, or flush the tank. Result? Find the outlet valve. How does it operate? How does the water left in the toilet bowl act as a trap? Find the siphon. How does it operate?

The plumbing system controls sewage disposal. *Sewage* consists of body waste and washings from sinks, basins, and tubs. It also contains waste from

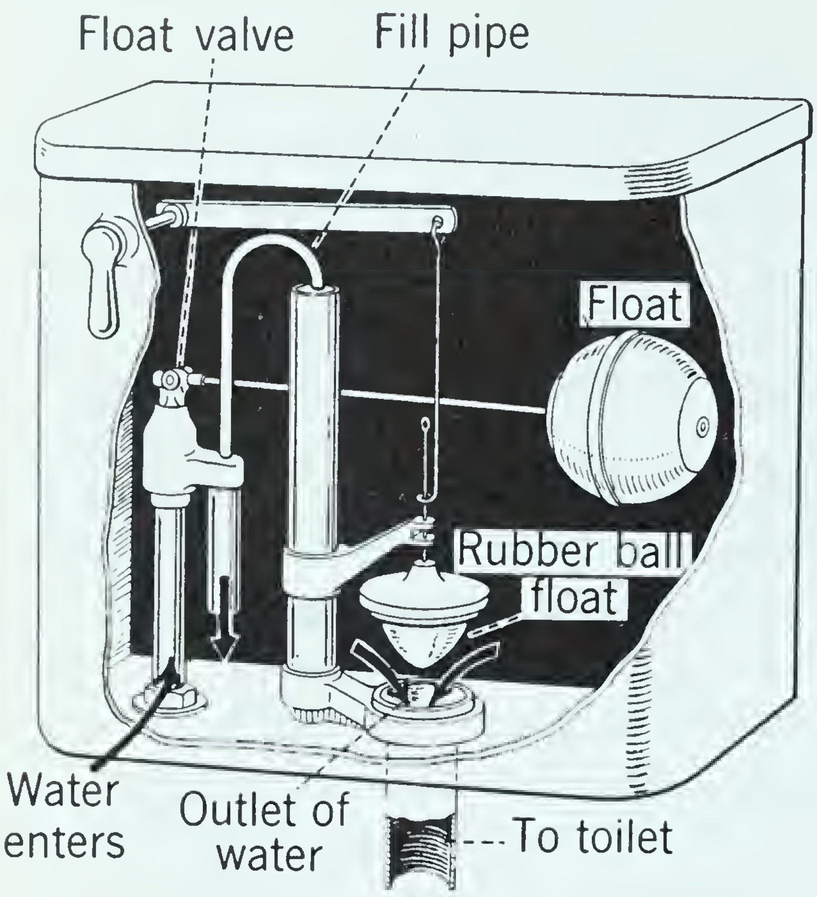


Fig. 6-24. The large float controls the amount of water that flows through the flush tank.

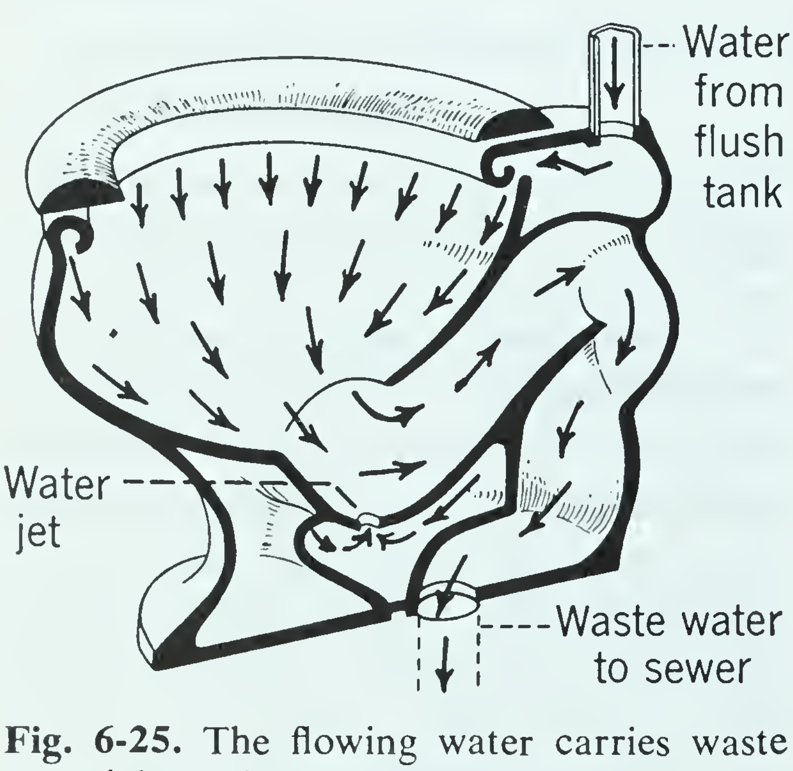


Fig. 6-25. The flowing water carries waste materials to the sewage system.

laundries, garages, shops, and streets, and refuse of any sort small enough to enter sewage pipes.

Sewage is dangerous for several reasons. Not only is it offensive to the nose, but it also is apt to have many kinds of disease germs in it. Flies breeding in sewage may carry deadly germs to our food and tables. Without proper plumbing, sewage can get into the water supply and spread disease.

This waste matter can be carried out of the house by running water or by the gravity system. All air vents should be kept open to prevent traps from acting as siphons. If this happens, all the water flows out of the traps and the sewer gases can enter the house.

Sometimes a single vent pipe is used for all the plumbing fixtures in the house. Notice in the diagram in Fig. 6-26 that the sewage pipes carry water away from all plumbing fixtures. Also notice that all these fixtures are provided with traps.

A meter measures the volume of water used. Water is sold to the public in two ways: (1) at a flat rate; and (2) by the thousand gallons. A *flat rate* means a certain price per year. The second method requires the use of a water meter. Water meters register in cubic feet or gallons. One cubic foot generally means 7½ gallons. Hence, to change the meter reading in cubic feet to gallons, multiply the number of cubic feet by 7½.

Water meters are of two kinds: (1) the *straight reading meter;* and (2) the *dial register meter*. The straight reading meter gives the reading in a straight line of figures.

The reading of the dial register is more difficult. The dial register has six circles on the dial (see Fig. 6-27). The one-foot circle is used only for testing. The other circles are labeled: 10, 100, 1,000, 10,000, and 100,000. The pointer of the 10 cubic feet turns counterclockwise. The pointer of each

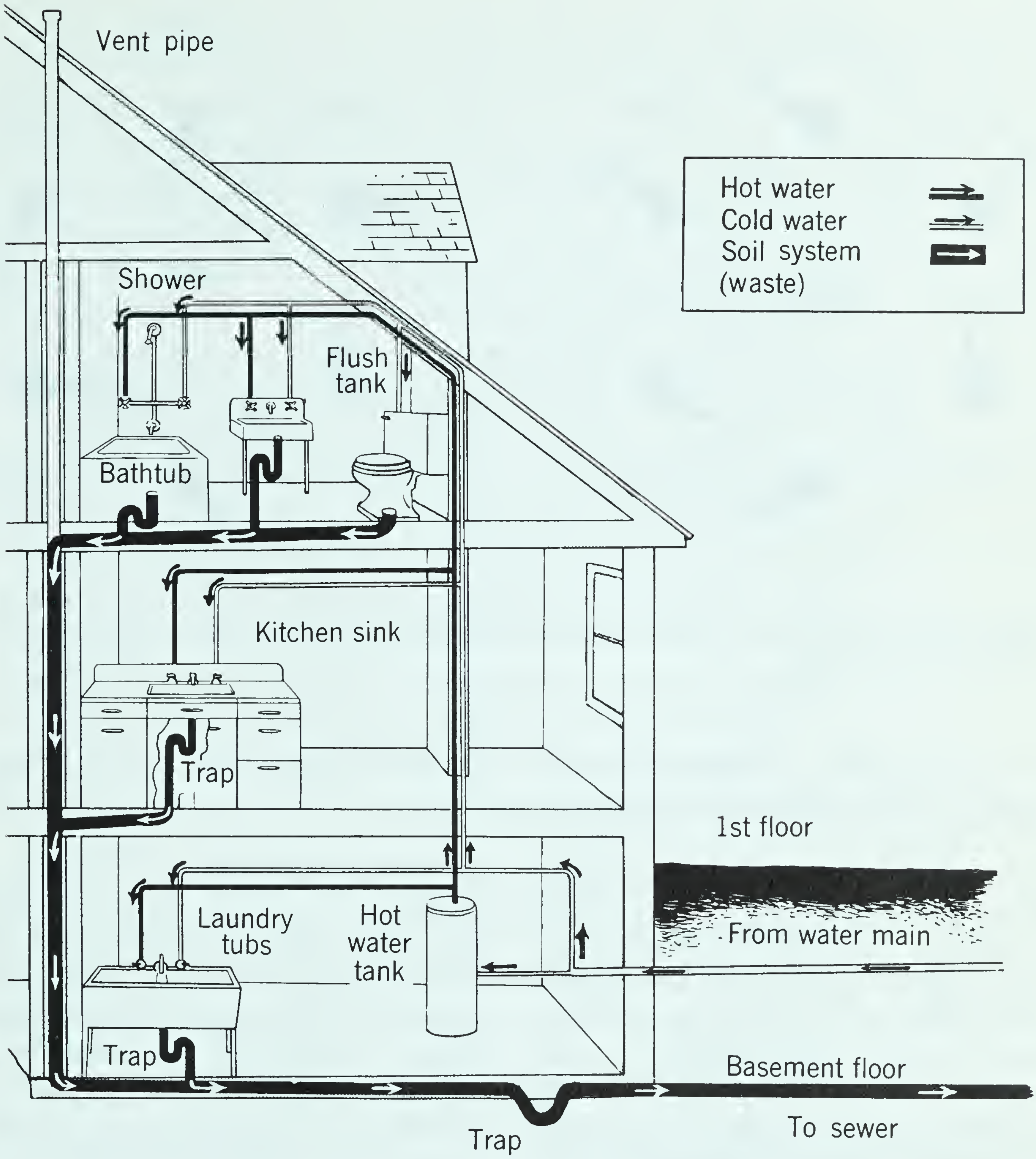


Fig. 6-26. The modern plumbing system provides a santitary method of bringing water into the house and removing waste materials. Air vents have been omitted.

higher circle turns in a direction opposite to the next lower one. Each circle is divided into ten equal divisions. One division of the 10-cubic feet circle registers one cubic foot, while one division of the 100-cubic feet circle registers ten cubic feet, and so on.

PUPIL ACTIVITY

Find the number of cubic feet registered for one week and find the cost. Turn on the faucet slightly and find the amount of water in pints, quarts, and gallons that leaks out in 10 minutes. Figure the amount that would run out in 24 hours; in a month; in a year. Find the cost of

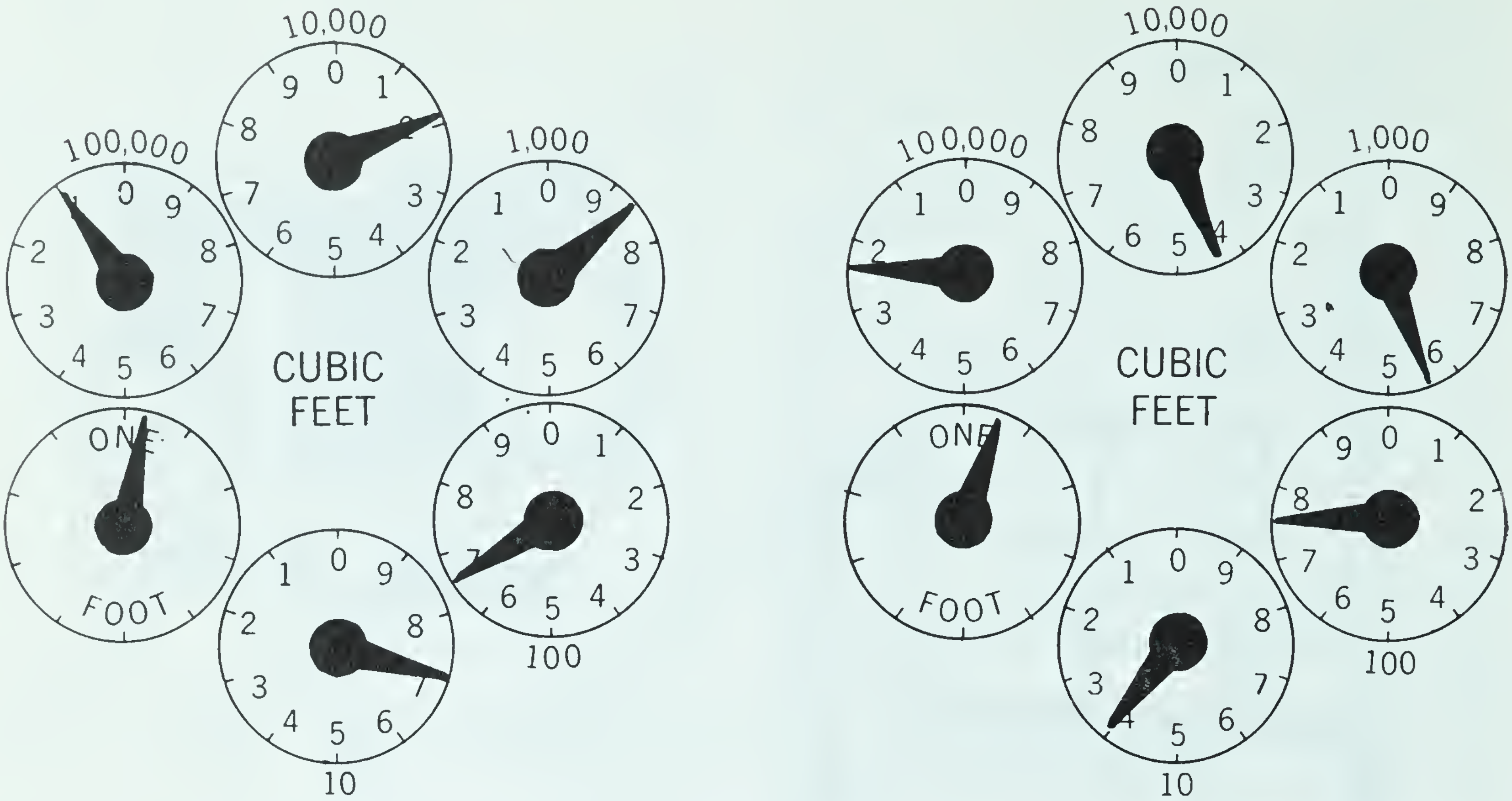
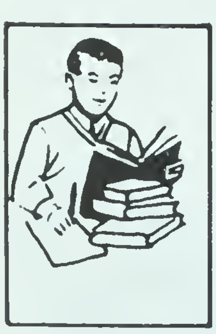


Fig. 6-27. Calculate the amount of water that was used in the period between the two readings of the meter.

your water supply. (Consult the water company's bills.) Figure the cost for one year. Multiply this by the number of houses in your city or locality. (Allow one house for each five people in the population.) What is the cost in your locality for one leaking faucet per family in one year? Is it worthwhile to repair leaking faucets? How efficient is your house's plumbing? Examine all faucets and flushing tanks at home. Be sure that none of them is leaking. Estimate the cost of the wasted water in your home per year.

REVIEW QUESTIONS

1. What is the air vent in a modern plumbing system? **2.** What are traps? What is their purpose? **3.** How are sewage and waste products removed from a house? **4.** What are the dangers in having an unsanitary plumbing system in a building? **5.** In what unit of measure is water sold in your community?



QUESTIONS FOR REVIEW AND DISCUSSION

1. When was the need of a safe water supply first recognized?
2. Why is a safe water supply system so necessary at the present time?
3. What gives water its taste?
4. What are the principal sources of drinking water?

5. What four systems are used to supply water to our houses?
6. What problems need to be considered in building reservoirs or water towers?
7. What forces water through the pipes to your house?
8. How does nature provide safe water?
9. How can you change salt water to fresh water?
10. Why are shallow wells dangerous?
11. Why are mountain streams good sources of safe water?
12. In what different ways can drinking water become contaminated?
13. How can sediment or solid particles be removed from water?
14. How can water be purified for drinking purposes if it contains dissolved materials? If it contains disease germs?
15. Why will filtering remove mud from water but not salt?
16. What methods can you use to test for impurities in water?
17. What is hard water? How can hard water be softened?
18. How does soap remove grease and dirt from clothing?
19. What does the plumbing system in a house include?
20. What are five good features of an efficient plumbing system?
21. Explain how impure water can spread contagious diseases.
22. What is the source of the drinking water you use at home?
23. Why is it necessary to prevent the discharge of waste materials into our lakes and rivers?
24. Why is it necessary to have traps in a plumbing system?
25. How are faucets used to control the flow of water in a house?
26. How is compressed air used to force water through the pipes in a house?
27. List some of the sources of water that would be safe to use without purification.

SPECIAL REPORTS AND PROBLEMS

1. Make a sand filter.
2. Make a charcoal filter.
3. Distill some water at home.
4. Report on your city water system and sewage disposal system.
5. Make a diagram of your plumbing system at home.
6. Replace a wornout washer on a faucet.
7. Tell how to get supplies of safe water on a camping trip.
8. Report on the various uses of distillation in industry.
9. Make diagrams to illustrate how a water-pressure system can be developed in a house not connected with a city water system. Explain the diagrams to the class.
10. Find the cost of water for your home for one year. Are the water bills about the same for each month? In which months does your family use the least water? In which months does your family use the most water?
11. Report on how water is purified in swimming pools.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: water cycle, condensation, gravity system for getting water, organic waste materials, distilling, filtering, coagulation, hard water, bacteria, alkali, sewage, aeration, air vent, trap in plumbing system?
2. Compare the properties of air and water. How is pressure developed in each? How is the pressure of each used?
3. Is cost the first consideration in building and maintaining a city water system? Why?
4. What are the advantages of a publicly-owned water system over a privately-owned system? What are the disadvantages?
5. What precautions does your community take to prevent impurities from getting into the water supply?
6. Why does it become necessary to develop water systems when large groups of people live together?
7. In what ways are our present water systems like those used in ancient times? How do they differ?
8. In what different ways can disease germs in water be destroyed?
9. What contagious diseases are spread by water? How do the germs get into the water?
10. How can a knowledge of the principles learned in this unit help you to make your home and community a healthier place in which to live?
11. What facts or scientific principles are applied, or made use of, in each of the following circumstances? If a theory helps in explaining some application, state how the theory helps the explanation.
    a. Water is made pure for drinking purposes by boiling.
    b. Drinking water has a taste.
    c. Water from mountains is safer than water from other sources.
    d. Water is distilled by boiling it and then cooling the vapor.
    e. Water towers are usually built on the highest elevations in a city.
    f. Dams are built in places where the level of the water can be raised as much as possible.
    g. Water held back of a dam for 10 miles has no more pressure than water held back one mile provided the height of the water behind the dams is the same.
    h. Water runs out of a faucet when it is opened.
    i. A water gauge is used to measure the height of water in a tank or boiler.
    j. Some large cities use compressed air in tanks rather than build several water towers.
    k. Several holes are punched in the sides of a can. The water flows out at greater speed at the lower opening if the can is kept full of water.

The old

FROM EARLY TIMES PEOPLE HAVE REALIZED THAT POLLUTED water causes disease and epidemics. However, they had no idea how impurities got into the water. They had not discovered the bacteria that caused disease. As people gathered in large cities, the problem of getting a safe water supply became more and more difficult. Many of the cities found it necessary to get their water from great distances.

The new

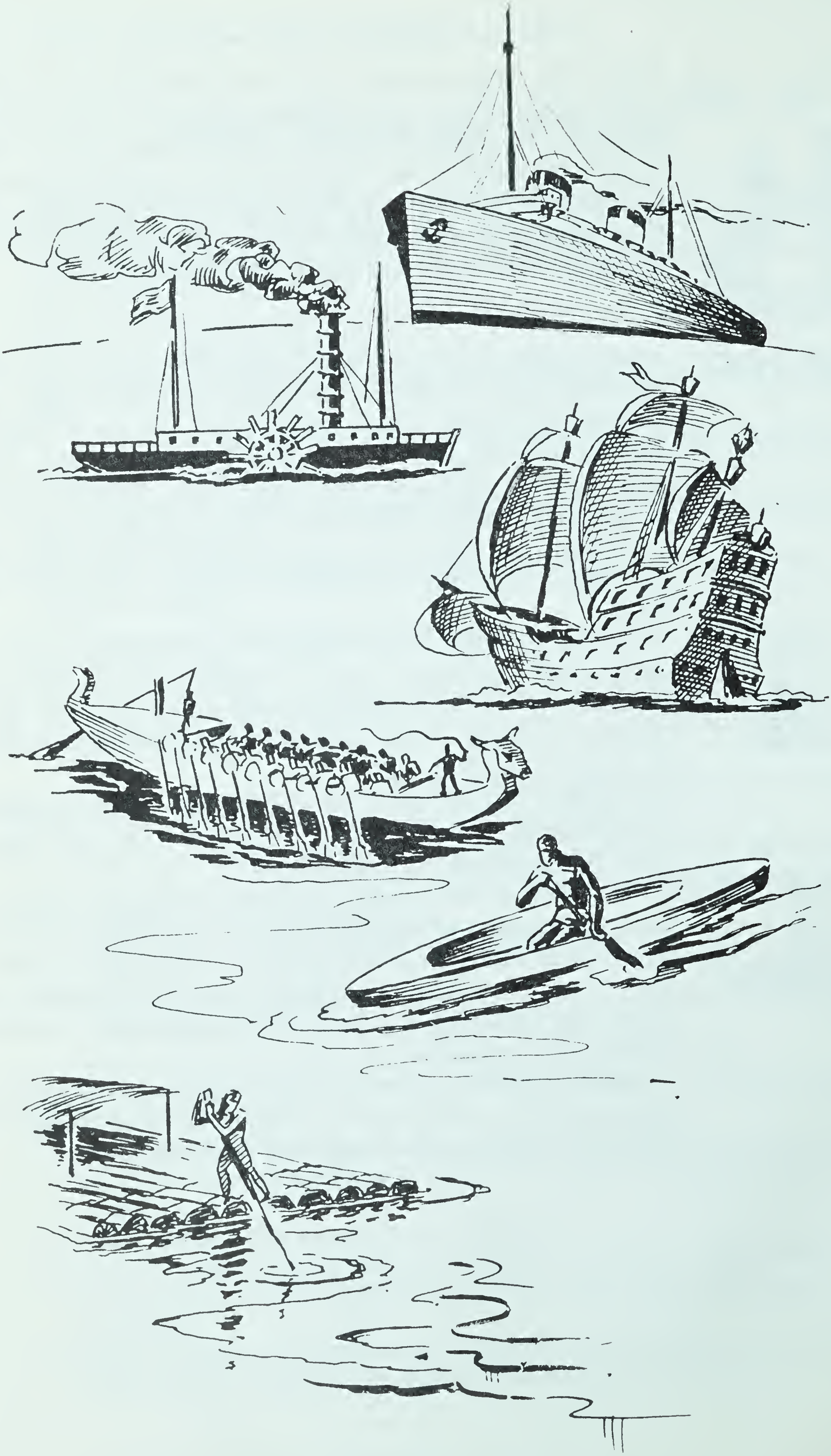
TODAY WE ARE ABLE TO OBTAIN WATER FROM SOURCES OVER 200 miles away. However, in thickly populated areas, the problem of securing a safe water supply still exists. Unfortunately, water in many of our lakes and rivers is becoming polluted. This is because some careless and ignorant people let sewage and other waste material flow into them, and thus contaminate the water. This waste material not only pollutes the water, but it may also destroy the plant and animal life there.

It is not necessary to let sewage flow into bodies of water, since science has found a way to dispose of it by chemical treatment. If we are to keep our water supply pure, we must all learn to dispose of our garbage, sewage, and other waste materials in a sanitary way.

Today, we can convert our garbage into useful fertilizer for agricultural regions instead of dumping it in areas where it will be carried to rivers and streams.

Practically all cities and towns of any size have water systems which yield a continuous supply of safe water. It is constantly being tested for disease germs. At the slightest indication of any contamination, scientific measures are taken to correct this situation, and the public is immediately warned to take extra precautions.

Modern plumbing systems provide convenience and safety undreamed of by our ancestors, giving us a constant supply of water, and efficiently disposing of all waste materials.



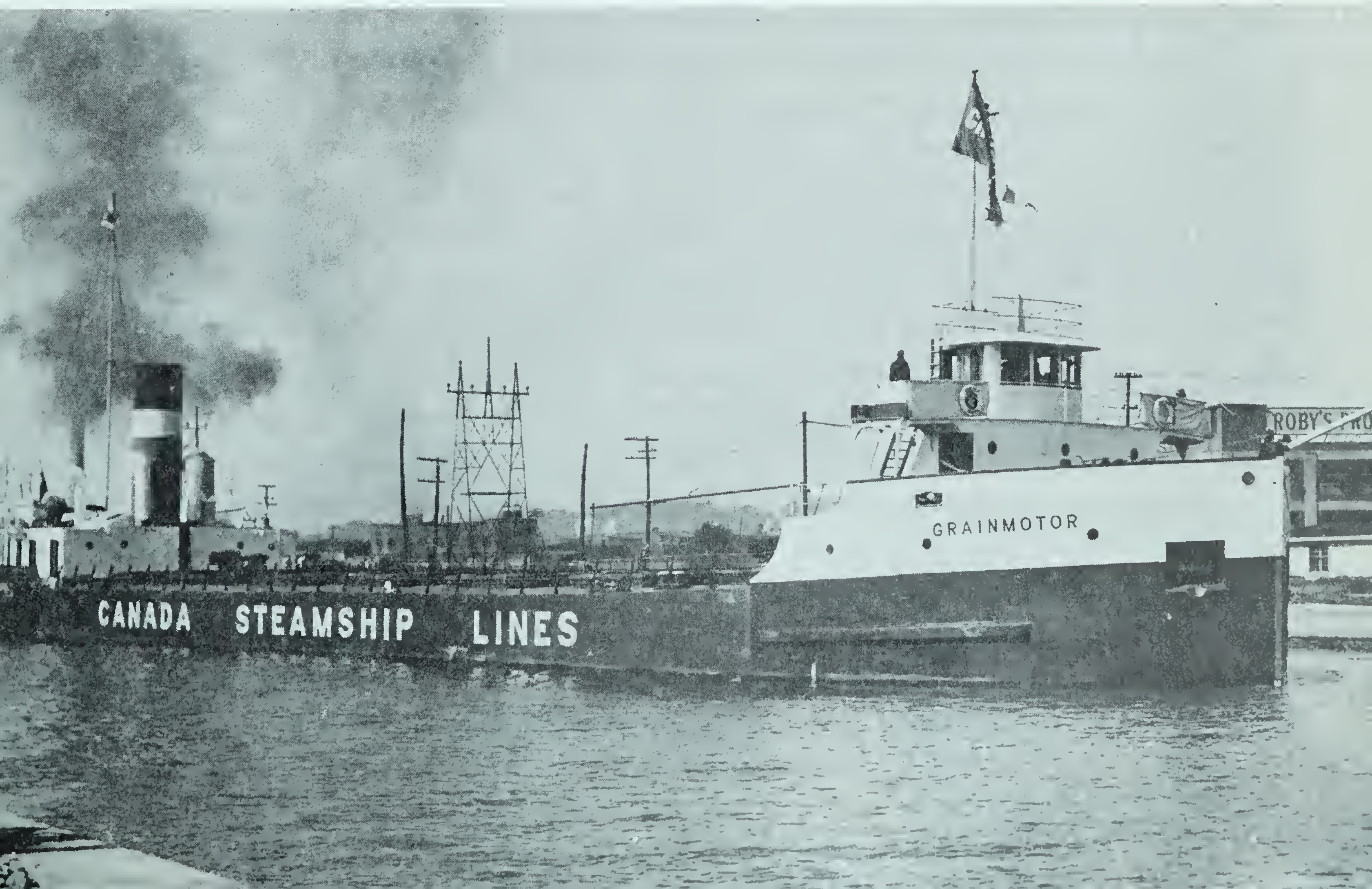
How has man learned to use water for transportation and machines?

UNIT 7

DISCOVERY AND PROGRESS

IN early times, man discovered that he could make a raft by binding several logs together with vines. This helped him to carry heavy objects from place to place. At first he steered it with his hands and feet. Later he used a flat stick, thus discovering the paddle. This made it easier for him to move the raft through the water. He was also able to change its direction and speed.

Then man learned that a hollow log was safer and that it could carry loads better. However, hollow logs were hard to find. Eventually he thought of hollowing out a log and later of building a frame and covering it with bark. From this idea came the first canoe. This progress which seems so easy to us took hundreds of years. You can trace this progress by looking at the series of drawings in the panel facing this page.



It was years later that man invented the first wooden rowboat. The large Roman galleys were merely huge rowboats. They had more than one deck and hundreds of men with oars to row the galleys through the water. Then the Vikings who lived in Norway and Sweden added sails to their rowboats. When they did this, the rowers had far less work to do because the wind did most of it.

Greater progress came when man found that he could combine paddles with wheels. The work of pushing the boat through the water required less effort than by using paddles alone. Then the steamboat was invented. In this vessel, an engine was used to turn the paddle wheels. John Fitch made a steamboat in 1785, and Robert Fulton made his famous *Clermont* in 1807, shown in the panel facing page 179.

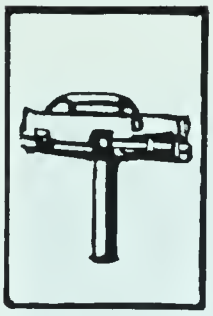
Development of the submarine and its use in naval warfare began as early as the Napoleonic Wars. In the strategy of both the First and Second World Wars the craft assumed enormous importance. The *Nautilus,* the first nuclear-powered submarine, was launched in the United States early in 1954. In recent years midget submarines, carrying a crew of two men, have been developed.

Two hundred years before the birth of Christ, King Hiero (*hee*-roh) of Syracuse, Sicily, ordered a crown made of pure gold. On its arrival he began to worry for fear that he had been cheated. He asked the famous Greek scientist, Archimedes (ar-kee-*mee*-deez), to find out if the crown was made of pure gold. This great man puzzled over his task, not knowing just how he would solve the problem. He did not dare return to the king without a solution. Getting into his bath one day, he noticed the water rising to a higher level as his body went below the surface. He leaped from the tub, dressed, and ran into the street crying, "Eureka!" ("I've found it!")

He tried the same experiment by comparing the amounts of water displaced by the crown and by a piece of pure gold of the same weight. The crown displaced more water than the piece of gold. Gold is very heavy and did not raise the water as much as the crown did. Therefore he concluded that some substance other than gold had been used to make the crown—possibly a mixture of gold and silver. Thus he proved a new scientific law known as *Archimedes' Law,* about which we will learn more in this Unit. Our modern knowledge of shipbuilding, pontoon bridges, and floating drydocks is based on this.

Many water-driven machines which we use today depend on the discoveries made in 1663 by the Frenchman, Pascal (pass-*kal*). He experimented with water pressure and the law he discovered is the basis for hydraulic presses and elevators.

Today we still use water for transportation and machines. Great ships carry people, crops, and industrial products across the oceans to all parts of the world. Giant turbines use the force of running water to generate electricity. Hydraulic devices are used in many modern machines.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How did early man travel on water? **2.** How can we use water to produce pressure? **3.** How can running water be used to do work? **4.** How does the depth of water or any liquid affect its pressure? **5.** Why do men build dams and reservoirs? **6.** Why do some substances float and others sink? **7.** How are boats propelled through water? **8.** How can an iron or steel ship float when iron is heavier than water? **9.** How is it possible for submarines to travel under water? **10.** Why is deep-sea diving so dangerous?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

bathyscaphe ..... (*bath*-ih-skafe), an underwater vessel, somewhat like a submarine, used by Auguste Piccard in underwater exploration.

bathysphere ...... (*bath*-ih-sfeer), a spherical underwater vessel used by William Beebe in underwater exploration.

buoyancy .... (*boy*-an-see), the lifting force of a liquid or gas upon a body immersed or partly immersed in it.

cylinder .... (*sih*-lin-der), a round chamber in an engine or some types of machines.

dynamo .... (*dy*-nah-moh), a machine which changes mechanical energy to electrical energy.

hydraulic .... (high-*draw*-lick), pertaining to water, or other fluids.

piston .... a sliding disk which moves back and forth when driven by some force in the cylinder of an engine or machine.

turbine .... (*ter*-bin), an engine driven by the pressure of a liquid or a gas on curved blades fastened so as to form a rotating wheel.

water displacement the volume or the weight of the water pushed aside by a body floating in it or submerged in it.

water turbine ..... a rotary motor propelled by the action of a current of water on a series of curved blades.

A What causes water to flow?

Water pressure is similar to air pressure. In Unit 2 you learned several important facts about air. You know that it has weight, exerts pressure, and is compressible. One cubic foot of air at sea level weighs only 1.25 ounces. You know, too, that the pressure of air at high altitudes is less than at low altitudes, and that air pressure at one point is equal in all directions. That is why flexible objects filled with compressed air tend to be round. Keeping these facts in mind, review for a moment what you learned in Unit 6.

Water, like air, also exerts pressure. The pressure of the air on earth is about 14.7 pounds per square inch. It takes only 34 feet of water to produce as much pressure as all the air does. Since water is so much heavier than air, it produces more pressure for the same depth.

Water pressure is equal in all directions and depends on the depth. You have already proved that water pressure varies with its depth; but what about pressure being equal in all directions? We can show this by an experiment.

DEMONSTRATION

Fasten a thin sheet of rubber over the mouth of a thistle tube (or small funnel). Fill a U-tube half-full of colored water and fasten it to a ring stand so that it is in an upright position as shown in Fig. 7-1. Connect one arm of the U-tube to the small end of the thistle tube with a long rubber tube. The U-tube is the gauge we use for measuring water pressure.

Lower the thistle tube into a jar of water to any marked depth. Without changing the level of the thistle tube, turn it so that it faces down, up, and to the side. Note the effects on the levels of the colored water in the U-tube. Results? Is the pressure the same in all directions at

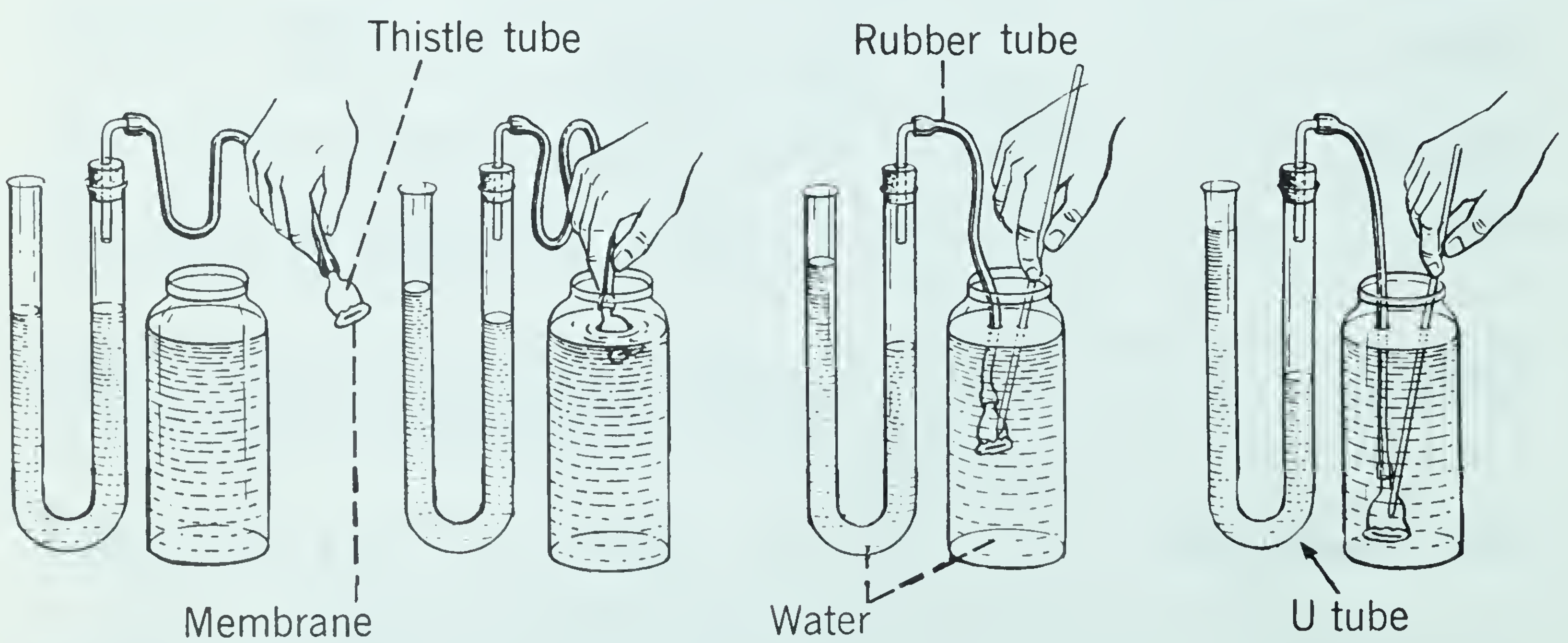


Fig. 7-1. Water pressure, like air pressure, is equal in all directions, and varies with the depth.

Fig. 7-2. The forces of pressure and gravity cause the water to flow down the hill.

the level selected? Try the same thing at a greater depth. Results? On what does pressure in the water depend? Would the readings be different if you put the thistle tube in a larger jar at the same depth? Try it and see.

Does the size of a reservoir govern the pressure? How can the pressure be increased at any given point? What is the effect of raising the level of water in a city reservoir?

These demonstrations show that the pressure in water increases with the depth. At any point, pressure is equal in all directions—up, down, and to the sides. But the pressure at a point 10 feet below the surface is twice that at a point only five feet below the surface.

If the pressure at any one point were not the same in all directions, water would flow from high pressure to low pressure areas. Then the pressures would become equal.

Water flows because of pressure and gravity. Water has weight. The deeper water is, the more it weighs for the same surface area. Also, the deeper water is, the greater the pressure is for each unit of area. Everyone knows that if a hole is made in the bottom of a tank of water, the water will flow out. But you may not know that the deeper the water is in the tank, the faster it will flow out.

If water flows down a hill, the force of gravity acts on it to make it flow faster. The steeper the hill is, the faster water will flow down it. Water flows from a high elevation to a lower elevation. It will continue to flow until it reaches a place like a lake or the ocean where all the water has the same elevation. When you drain the water from the radiator of an automobile, it flows out rapidly at first. But it slows down as it continues to drain. Why is this?

REVIEW QUESTIONS

1. In what ways are air pressure and water pressure alike? **2.** What determines the pressure in water? **3.** Is water pressure equal in all directions at the same point or level? **4.** Is it the same at all levels? **5.** How does a dam increase water pressure? **6.** What makes water flow? **7.** How does gravity cause water pressure?

B How is the force of moving water used?

Water wheels operate by the force of falling or flowing water. Falling water exerts a force which will turn a water wheel placed in its path. The farther the water falls, the greater is its force.

Still water contains an enormous amount of stored energy. When it begins to move, the stored energy is changed into the energy of motion. This is why running water will cause a wheel placed in it to turn.

DEMONSTRATION

Attach a water wheel to the faucet, as in Fig. 7-3. The connections should be made so that water does not leak between the faucet and the wheel. Open the faucet slowly. Result? Then open the faucet so that it will be wide open. What causes the water wheel to rotate? What determines the speed with which it rotates?

In Fig. 7-4 are shown three older types of water wheels. Under what conditions would each be most effective?

The water turbine is a form of water wheel. If you live in a community which has a large source of water power nearby, your electric company may use a water turbine to supply electricity. A ***turbine*** (*ter*-bin) is an engine driven by the pressure of a liquid or a gas on curved blades fastened to a turning shaft.

The shaft turns a ***dynamo*** (*dy*-nah-moh) which is a machine used to change the mechanical energy of the turbine into electrical energy. Thus the force of the moving water is transformed into electricity.

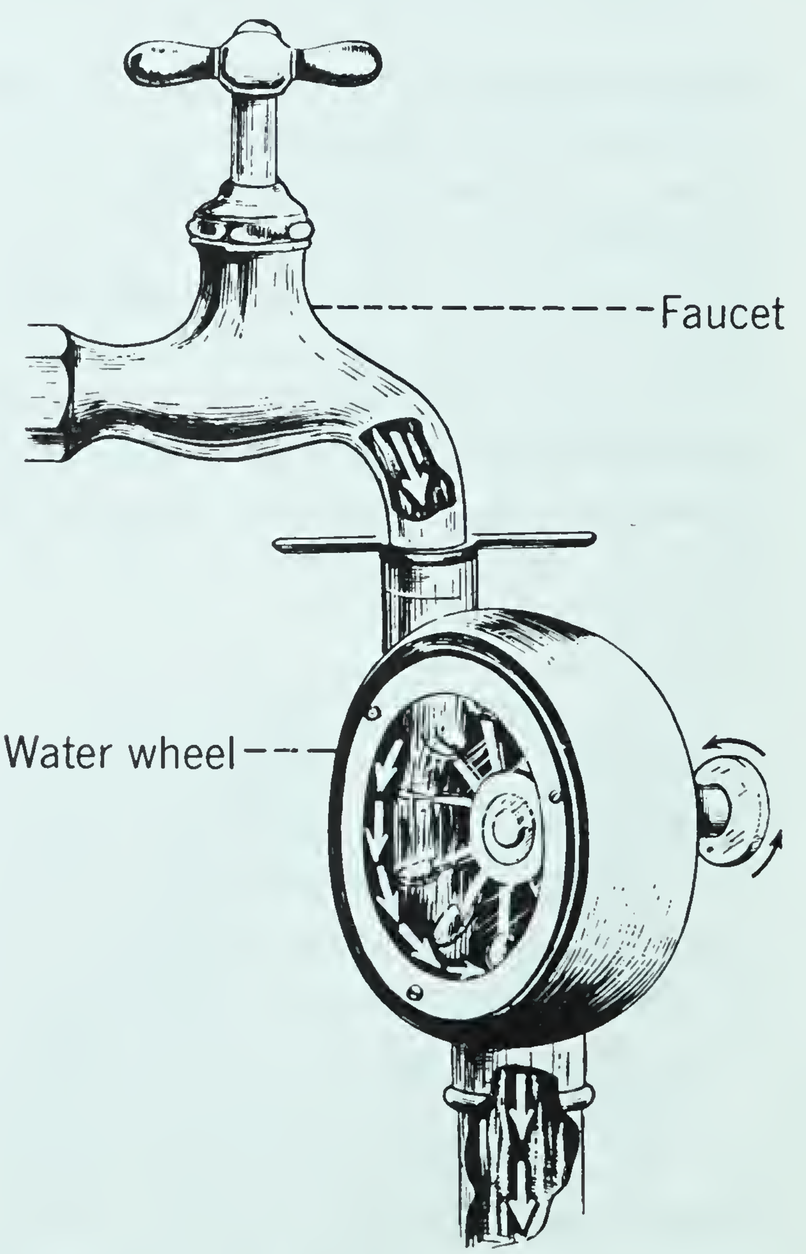


Fig. 7-3. The flowing water from the faucet rotates the water wheel.

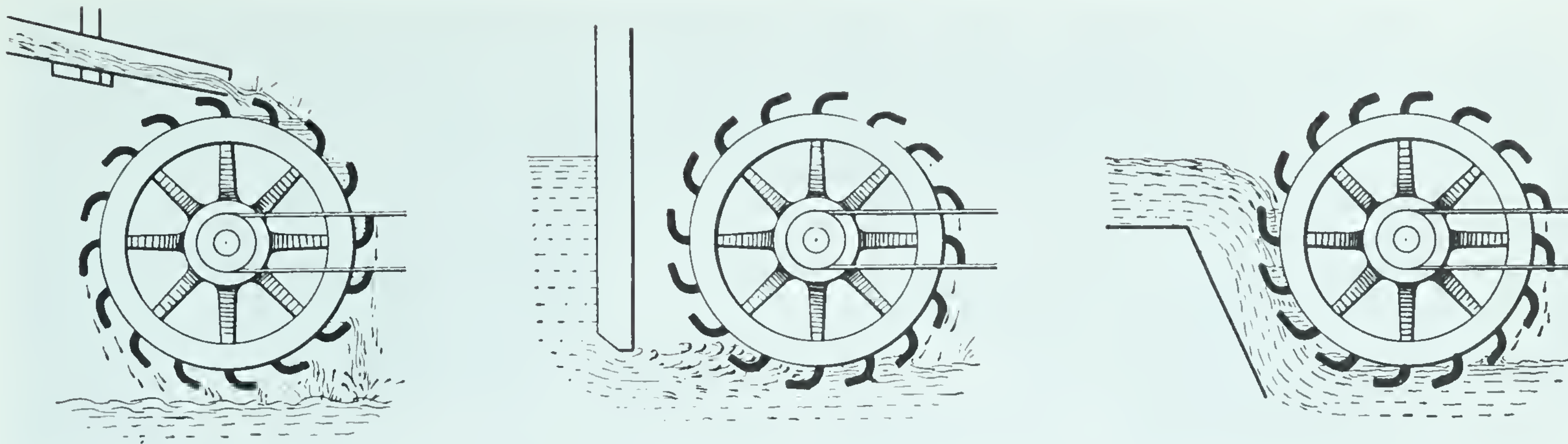


Fig. 7-4. These three diagrams show older types of water wheels which operate on the same fundamental principle. These were used before the turbine (Fig. 7-5) was developed.

A water turbine in a modern power plant works something like the water wheel. It has many blades shaped much like the blades of a propeller. It is enclosed at the bottom of a vertical pipe, through which water falls with great force from above. As this falling water goes through the blades of the turbine, its force causes the turbine to turn. As the turbine turns, it drives the dynamo which generates electricity.

Power plants get energy from three sources. These are: (1) *water;* (2) *fuel;* and (3) *wind.* Water furnishes about 20% of all power used. Fuels furnish about 78%, and wind supplies the remaining 2%. Wherever water under pressure is available in large quantities, water power is cheaper than power obtained by the use of fuel.

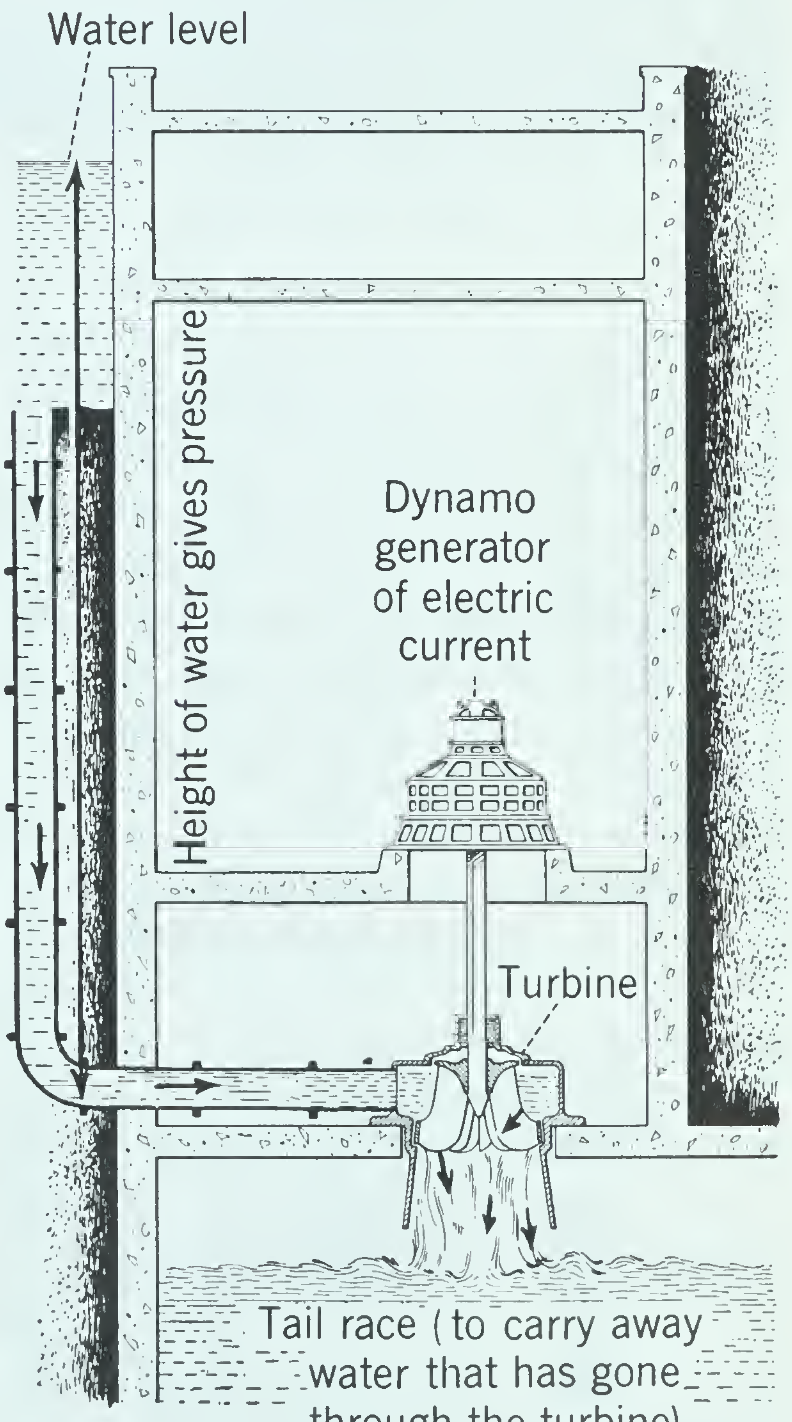


Fig. 7-5. The turbine uses the force of falling water to generate electricity.

REVIEW QUESTIONS

1. What force makes water wheels turn? **2.** What is a dynamo? **3.** What is a water turbine? **4.** What is the source of the energy which makes the turbine rotate? **5.** What are the three main sources of power? **6.** What per cent of the total power is obtained from each source?

C What makes objects float or sink?

Objects will float or sink in water depending on the upward push of water. Two boys were making a raft. One of them suggested using empty tin cans to help support the raft. The other boy said, "No, we cannot use metal of any sort because metal will sink." Was he right? How can metal be used in making a boat that will carry a load?

It is comparatively easy to understand why wooden rafts float, but it is not so easy to understand why steel battleships float. You know that some objects float in water while others sink. But why does a hollow rubber ball float while a solid rubber stopper of the same weight will sink? Why do some floating objects project out of the water more than others? What would this indicate about their relative weights?

DEMONSTRATION

Fill an overflow can up to the spout with water. Weigh a dry beaker. Then set the beaker to catch the overflow. Weigh a dry block of wood. Lower the block into the overflow can and catch the water that overflows in the beaker (see Fig. 7-6). How much does the block weigh in air? How much does the overflow water in the beaker weigh? How do the two weights compare?

Repeat, using a piece of iron or a glass stopper, suspended from a spring balance. Weigh the object in air. Then weigh it when it is submerged in water. Compare the apparent loss of weight of the object in water with the weight of the water displaced. Result? Why does the object sink?

These demonstrations show us that a floating body displaces its own weight of water. They show also that the apparent loss of weight of a submerged object is equal to the weight of the water it displaces. This is an example of *Archimedes'* (ar-kih-*mee*-deez) *Law*.

The same principle applies to objects in air. An object under water or

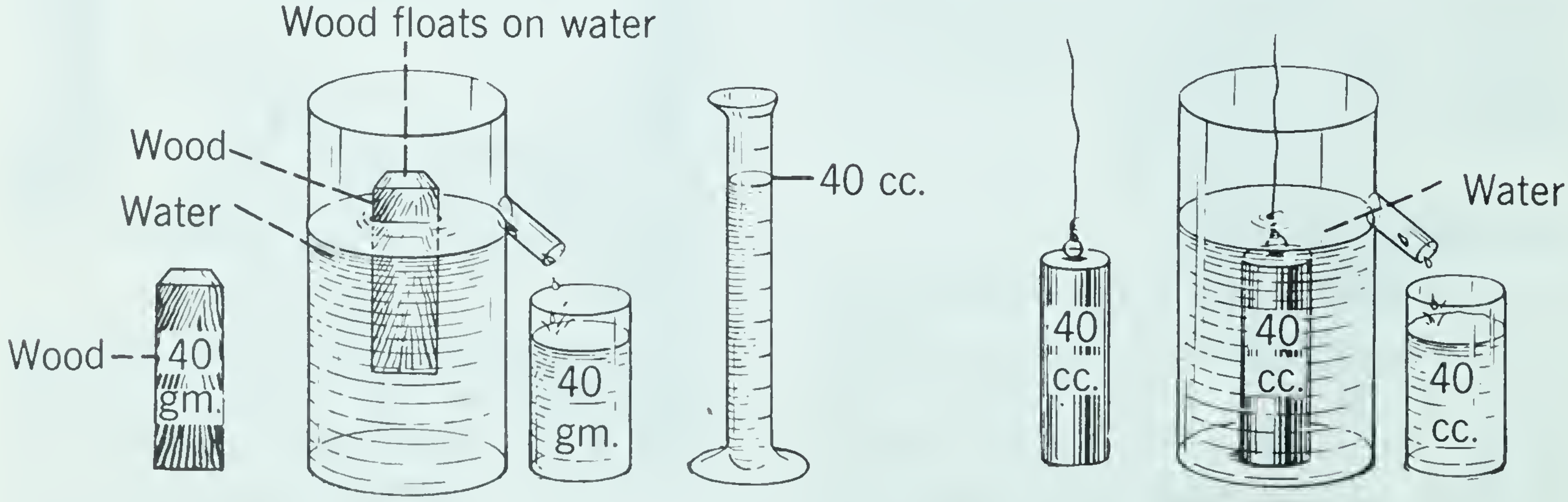


Fig. 7-6. The object lighter than water floats, displacing its own weight of water. The object heavier than water sinks, displacing a volume of water equal to its own volume.

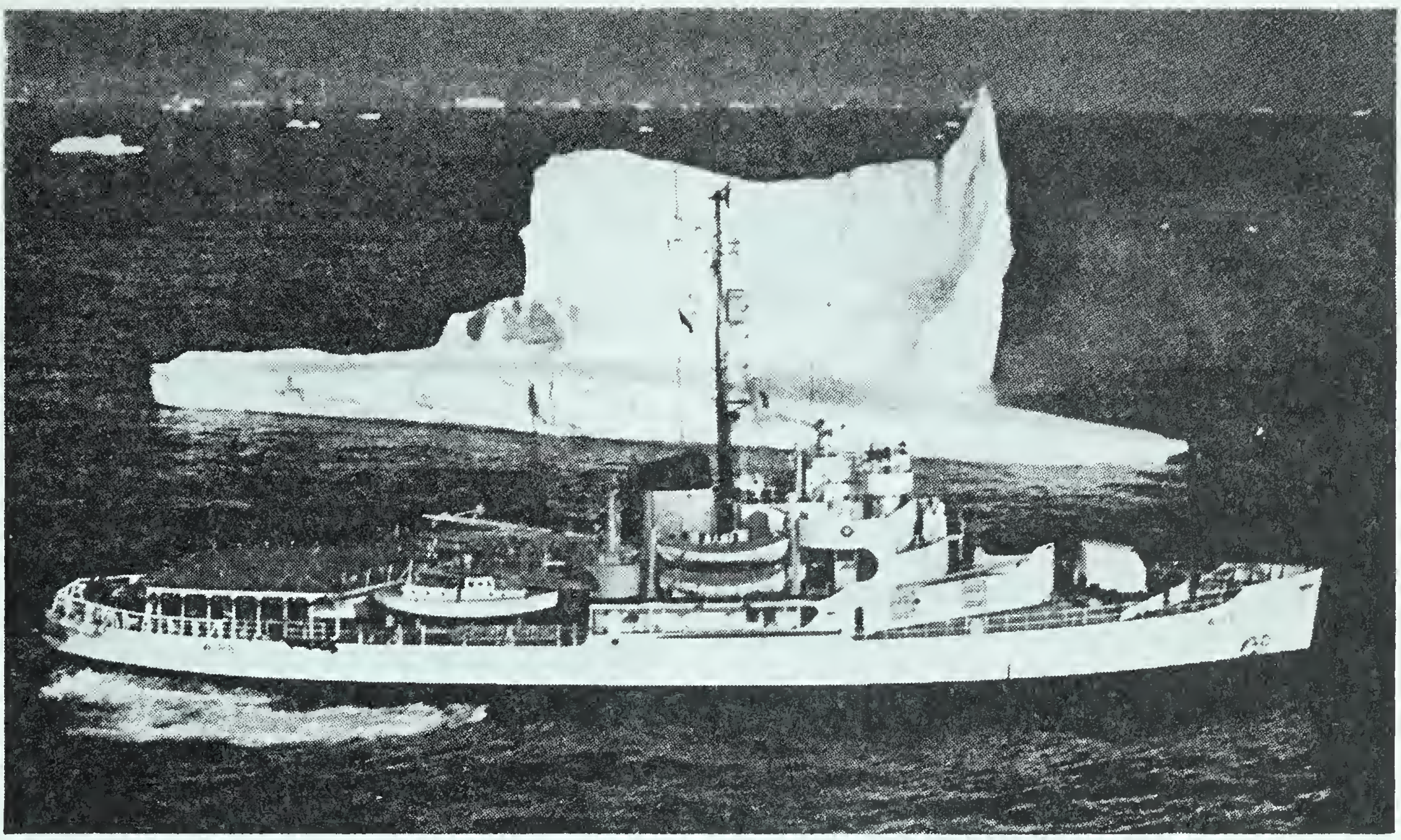


Fig. 7-7. An iceberg, a hazard to navigation, floats with about nine-tenths of its volume beneath the surface of the water.

in air is thus buoyed up or floated by a force just equal to the weight of the water or air displaced. If a block of wood weighing 60 pounds floats on water, it will displace its own weight of water, or 60 pounds of water. The volume of water displaced will be almost one cubic foot. For every cubic foot of water displaced, a weight of 62.4 pounds can be supported. If 1,000 cubic feet of water are displaced, the water can support 62,400 pounds.

DEMONSTRATION

Fill a test tube (50 or 60 cubic centimeter size) about one-third full of sand. (Your instructor will explain to you about *cubic centimeters* and also about *grams* which are units of measurement in the *metric system.*) Weigh it. Add or remove sand until the total weight of sand and test tube is exactly 40 grams. Fill a 200 cubic centimeter cylindrical graduate to the 155 cc. mark. To read the water level, hold the eye on a level with the water surface and read the lower surface of the film you see. Float the tube of sand in the water and notice how much water is displaced.

Balance exactly a dry 25 cc. graduate on the scales. Fill with water to the 25 cc. mark. How much does the weight increase? What is the weight of 1 cc. of water?

What is the weight of the water displaced by the 40-gram floating object? What weight of water would a floating body weighing 100 grams displace? Make a general statement concerning floating bodies.

A floating body sinks until it displaces its own weight of the fluid (see Fig. 7-8). Thus a piece of cork one-

fourth as heavy as the same volume of water will sink until one-fourth of it is under water. A piece of pine wood one-half as heavy as the same volume of water will sink until one-half of it is under water. A piece of tin will sink to the bottom because it does not displace its own weight of water. If you shape the tin into a cup or boat, it will float because it can displace its own weight of water and more.

A steel ship floats for the same reason when it displaces its own weight of water (Fig. 7-9).

Likewise, a balloon rises because it and its contents are lighter than the volume of air it displaces. It will continue to rise until the weight of the air displaced by the balloon equals the weight of the balloon and its contents.

These facts show that water and air exert an upward lifting force. This lifting force, which any liquid or gas exerts on a body immersed in it, is called ***buoyancy*** (*boy*-an-see).

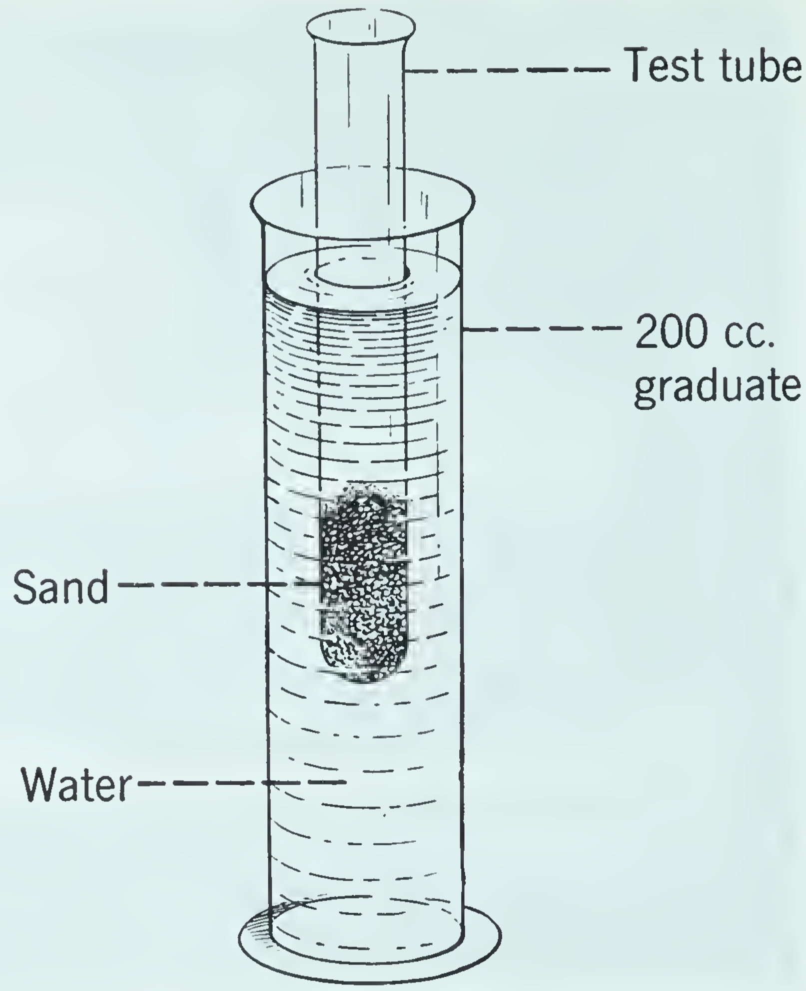


Fig. 7-8. Why do objects float in water?

Buoyancy explains why you can easily lift large stones under water, but cannot lift the same stones when they are on land. It also explains why a diver with his heavy equipment can move about under water, but must be

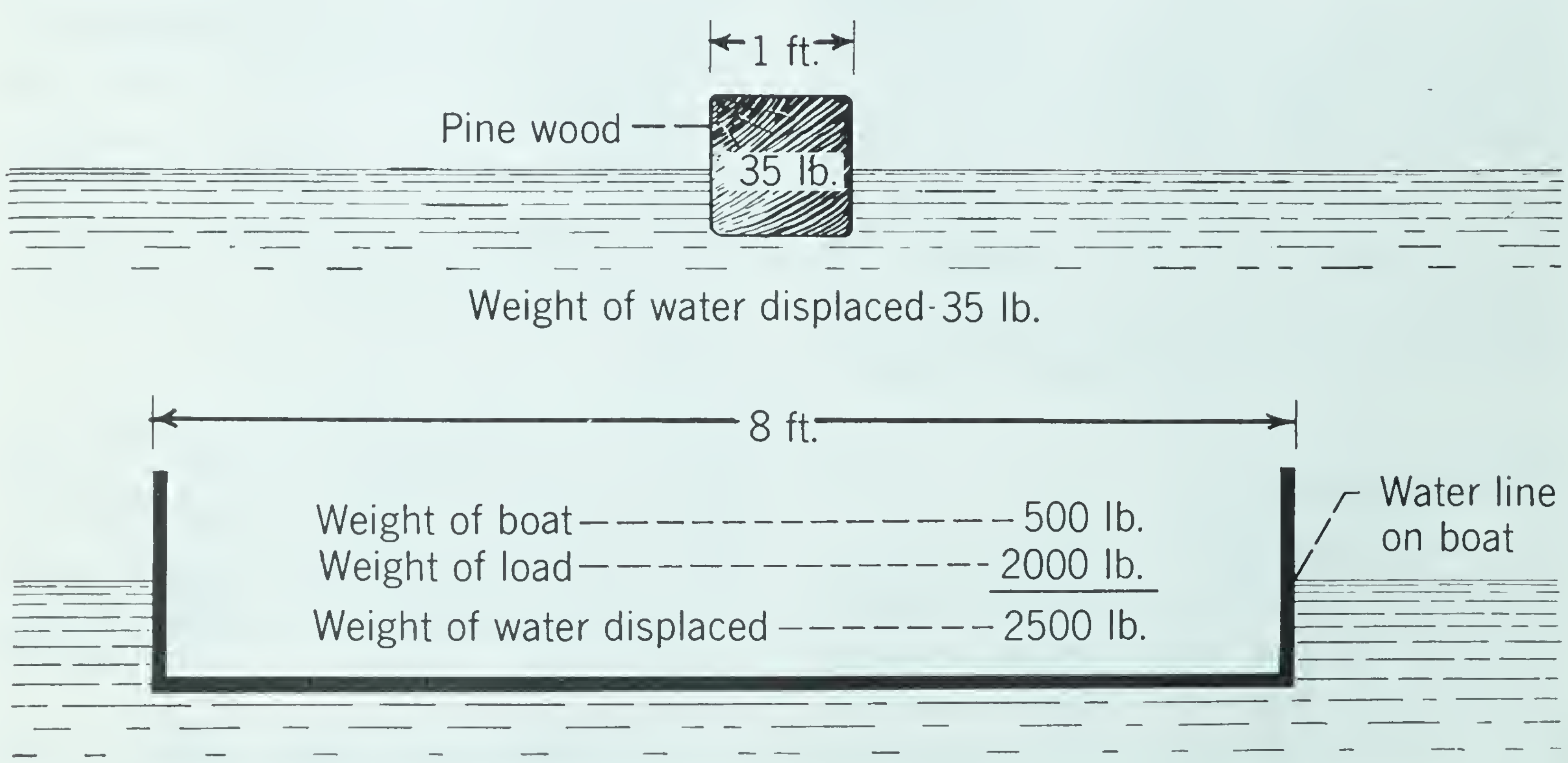


Fig. 7-9. A boat, or any other floating object, sinks until it displaces its own weight of water.

assisted when he comes out of the water.

We can summarize the principles involved in floating and sinking in the following statement: *objects will float if the buoyancy of water or air is greater than the pull of gravity; but they will sink if the buoyancy of water or air is less than the pull of gravity.*

The force of inertia helps to float objects heavier than water. You know how sleds slide easily over snow or ice. Perhaps a few of you have enjoyed the sport of riding an aquaplane behind a motor boat. The passenger mounts in shallow water just as the motor boat starts. The aquaplane then begins to slide over the water as the speed of the boat increases. Fig. 7-11 shows the same principle in the use of water skis.

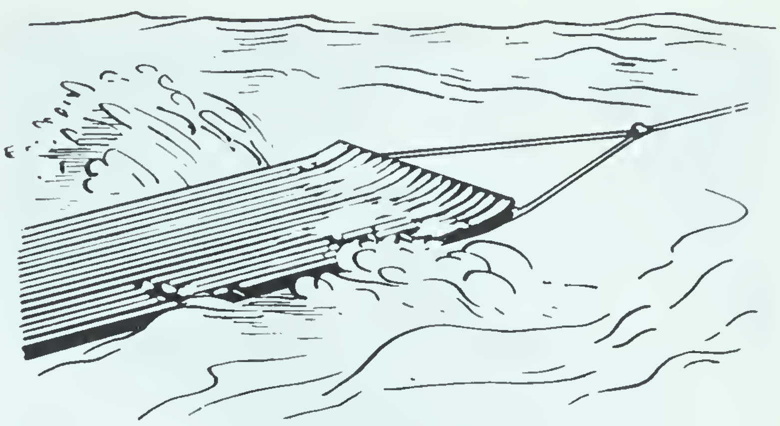


Fig. 7-10. Because of inertia of water, the moving aquaplane does not sink.

PUPIL ACTIVITY

Make an aquaplane out of a piece of sheet tin or zinc, about 6″ x 9″. Bend one end slightly upward. Fasten a string to the bent end, and try drawing it slowly along the water in a pond or in the bathtub. Now draw it rapidly. Result? Try loading the plane and drawing slowly, then rapidly. Result? Does pulling it rapidly keep it afloat? Is the water re-

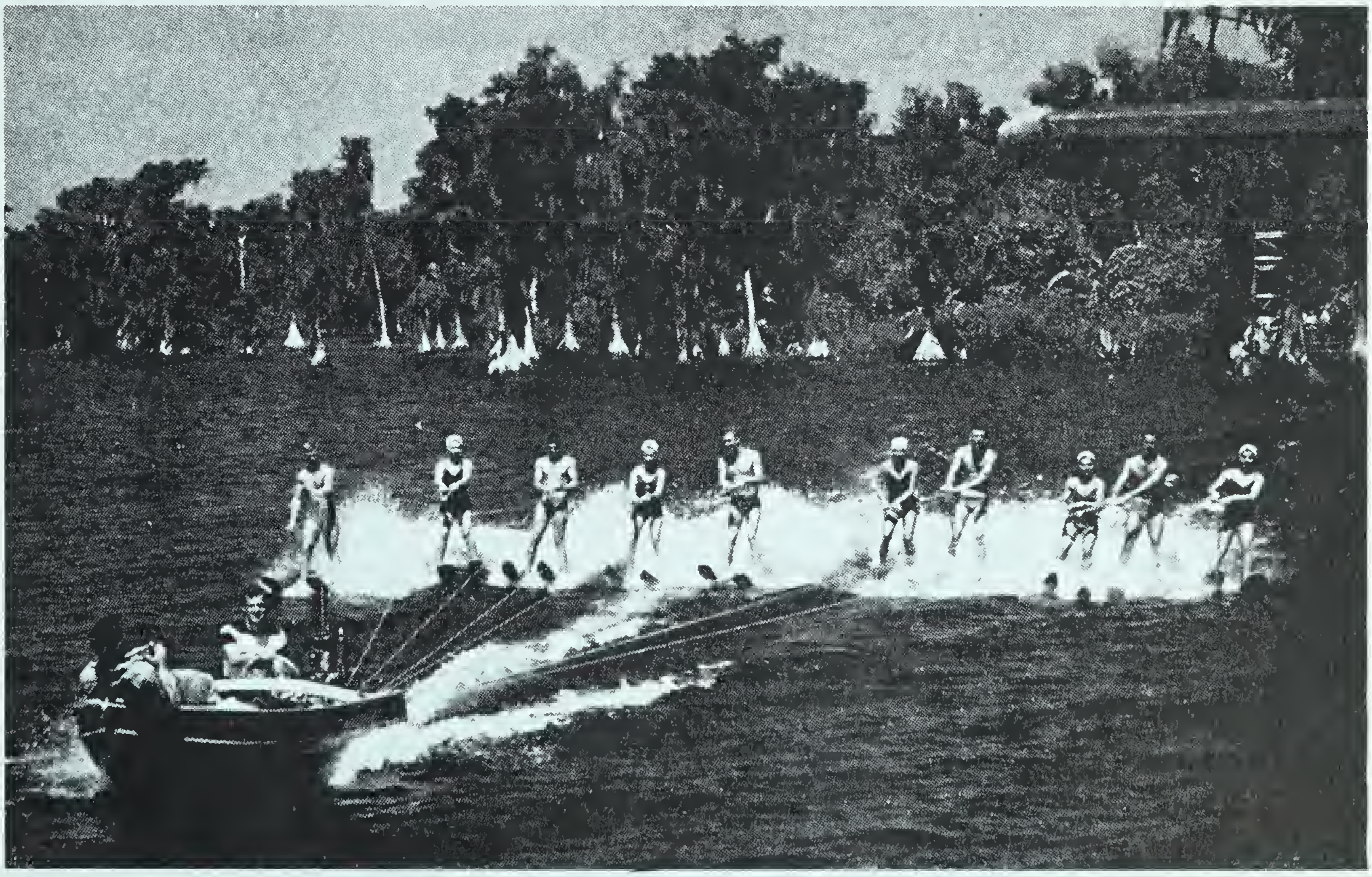


Fig. 7-11. The speeding motor boat makes it easier for these water skiers to remain on the surface of the water.

moved from a small space just back of the plane? Why do speed boats ride so high in the water? Could you float the aquaplane by holding it in a rapidly flowing stream? Explain. When will an aquaplane float? When will it sink? Explain.

Drop the plane flat on the surface of the water. Result? Quickly strike the surface of the water with the flat of your hand or with a flat board. Result? Does water act much like a solid body when you strike it quickly? Why not dive so as to strike the water flat? Does water offer more resistance when an aquaplane is moving slowly or rapidly? Explain. What do we mean by inertia?

When the aquaplane is pulled rapidly across the water, it does not sink because the water has considerable inertia. The faster the aquaplane moves, the more weight it will support. The faster it moves, the higher the aquaplane will ride on the water.

Water skis work on the same principle as the aquaplane. So does the old trick of skipping flat stones over the water. Speed boats are frequently built so that they will ride over the water in the same way as the aquaplane.

REVIEW QUESTIONS

1. How much water does an object lighter than water displace when placed on water? **2.** How much water does an object heavier than water displace when it sinks in water? **3.** Why do objects appear to weigh less in water? **4.** If a boat weighs 10 tons, what is the weight of the water it will displace? **5.** State the law that Archimedes discovered. **6.** How can aquaplanes be made to stay on the surface of water when they are heavier than water?

D How are boats propelled through water?

In order to move boats and ships through water, you must exert some force against the water. When you paddle a canoe or row a boat, you push against the water in one direction and your craft is moved in the opposite direction.

Some small boats and all ships use propellers which drive them through the water. This is the same principle by which an airplane propeller produces its thrust. Small craft use gasoline engines for power. Larger vessels have Diesel or steam engines.

Submarines move on the surface as well as under water. A submarine is like any other ship when it moves on the surface of the water. But it also

Fig. 7-12. These girls are paddling in one direction. Why does the canoe move in the opposite direction?

does other things that a regular ship cannot do. It travels under the surface of the water, and rises and sinks quickly. It must be built to withstand the increased pressure of the water when it sinks. Sinking to a depth of 25 feet increases the pressure on each square foot by about 1,600 pounds. Air must be supplied to the crew while under water.

The ordinary power for propelling the submarine on the surface cannot be used under the water. If a steam or gas engine were used, it would consume a large supply of air in combustion. The engine would also produce a great amount of heat. Most submarines use electrical power for propelling the boat under water. Storage batteries usually supply the electrical energy. The newest submarines use atomic power plants. In theory they can re-

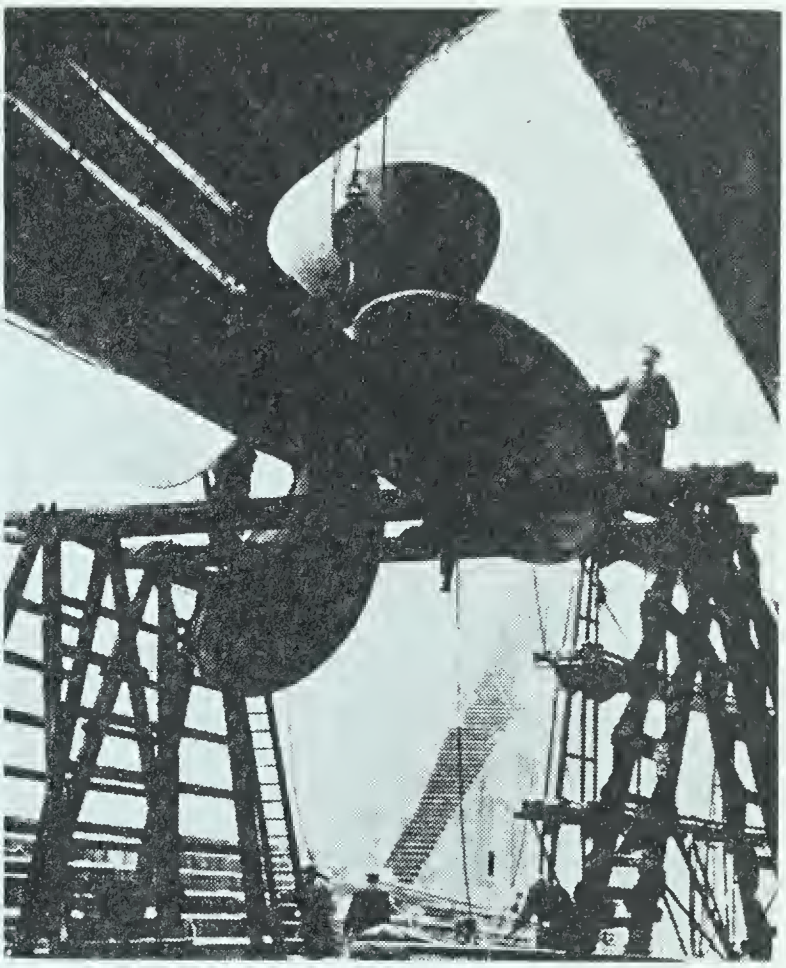


Fig. 7-13. This is one of the propellers of the *Queen Mary*. Most of the large ocean liners and naval vessels have four of them. How do the propellers move the ship? In what ways are they like airplane propellers? How are they different?

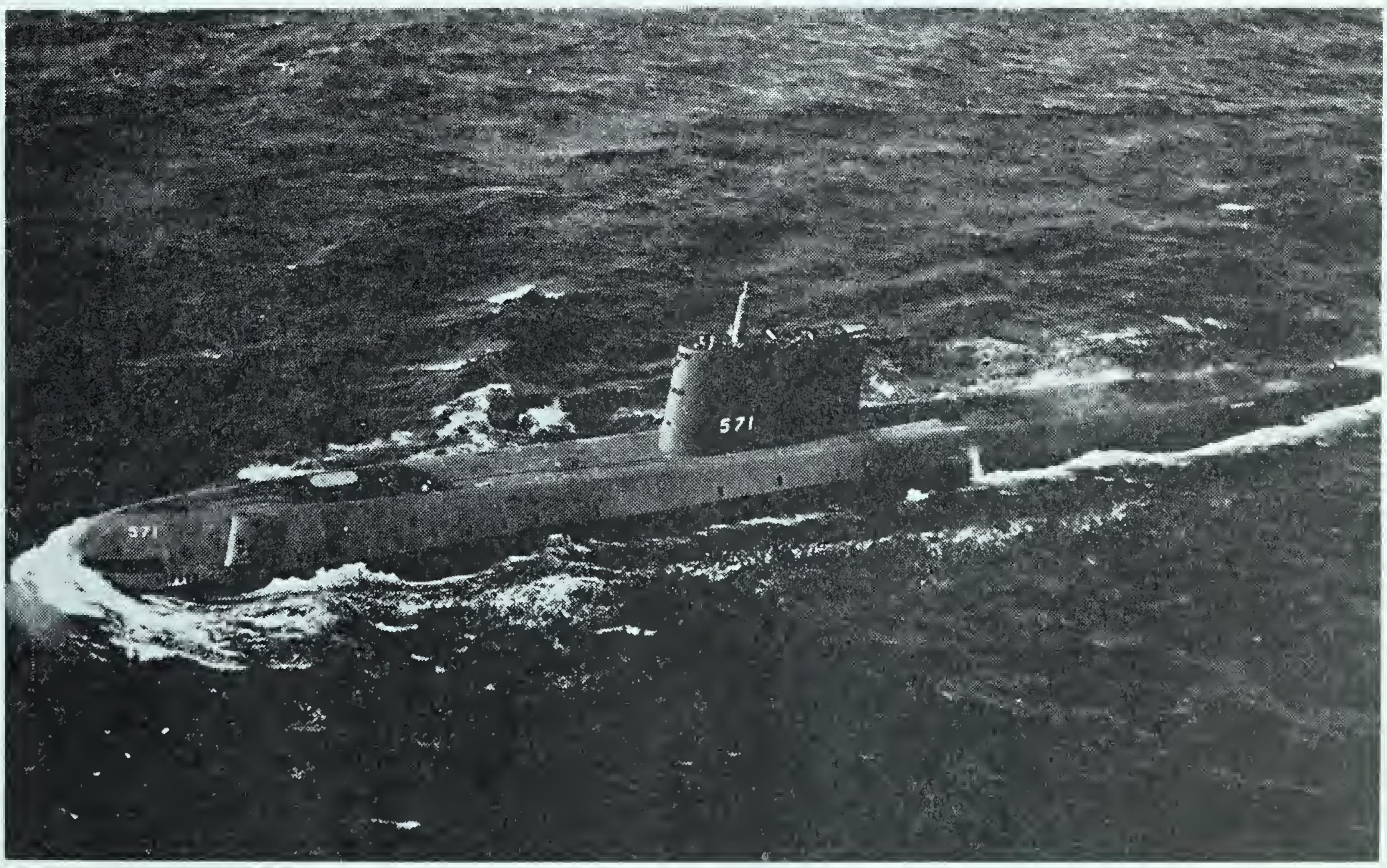


Fig. 7-14. This is the USS *Nautilus*, the first atomic-powered submarine.

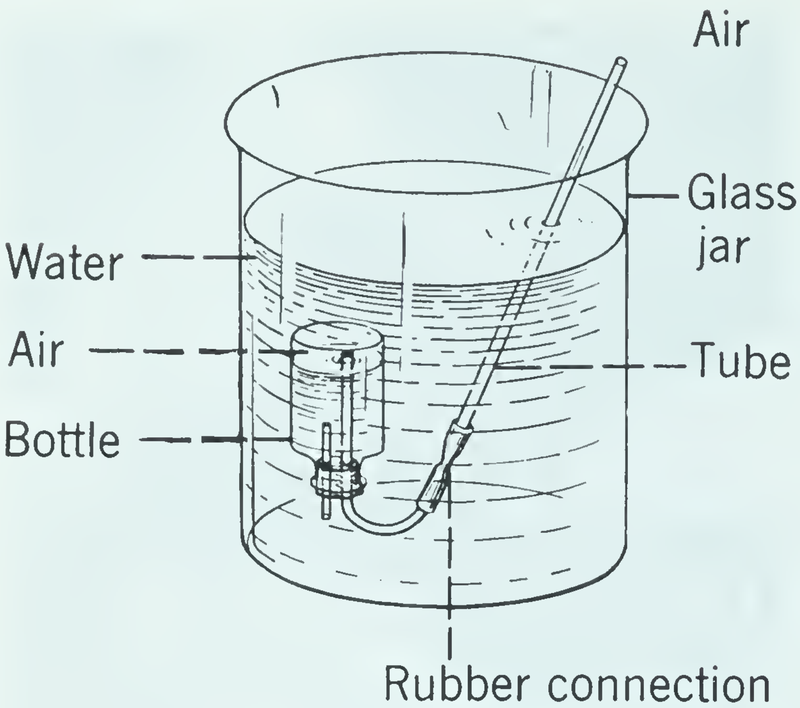


Fig. 7-15. The water-filled bottle will rise when air is forced into it.

main under water for weeks or even months at a time. However, the endurance of the crew seems to be the limiting factor in determining how long an atomic-powered submarine can stay submerged.

DEMONSTRATION

Put a two-hole rubber stopper in a bottle as in Fig. 7-15. Put a glass tube through one hole in the stopper. Put a bent glass tube through the other hole in the stopper. Then with a piece of rubber, connect this tube to a longer one. Put the bottle in a large jar of water. Does the bottle float? Now suck on the long tube. Does the bottle sink deeper? Suck out enough air to make the bottle sink to the bottom. Blow air through the long tube into the bottle. Is water forced out of the bottle? Does the bottle rise?

Submarines have ballast tanks into which water can enter. When enough water is let into the tanks, the submarine will submerge. When compressed air is forced into the ballast tanks, the water is forced out and the submarine rises. In this way, the weight of the submarine may be made greater or less than that of an equal volume of water.

The human body cannot easily withstand sudden changes of pressure. Deep-sea divers are equipped with suits into which air is pumped to equalize the water pressure as they go down into the water. They must be lowered slowly so their bodies will adjust to the increased pressure. In coming up, they must be raised much slower than when they went down or they will suffer great pain as the pressure on their bodies is reduced.

Skin divers can go down quite a distance under water. They also must submerge and rise slowly to avoid serious discomfort from rapid changes of pressure.

When Dr. William Beebe went

Fig. 7-16. Air is pumped into the suits of deep-sea divers to equalize the water pressure as they go down.

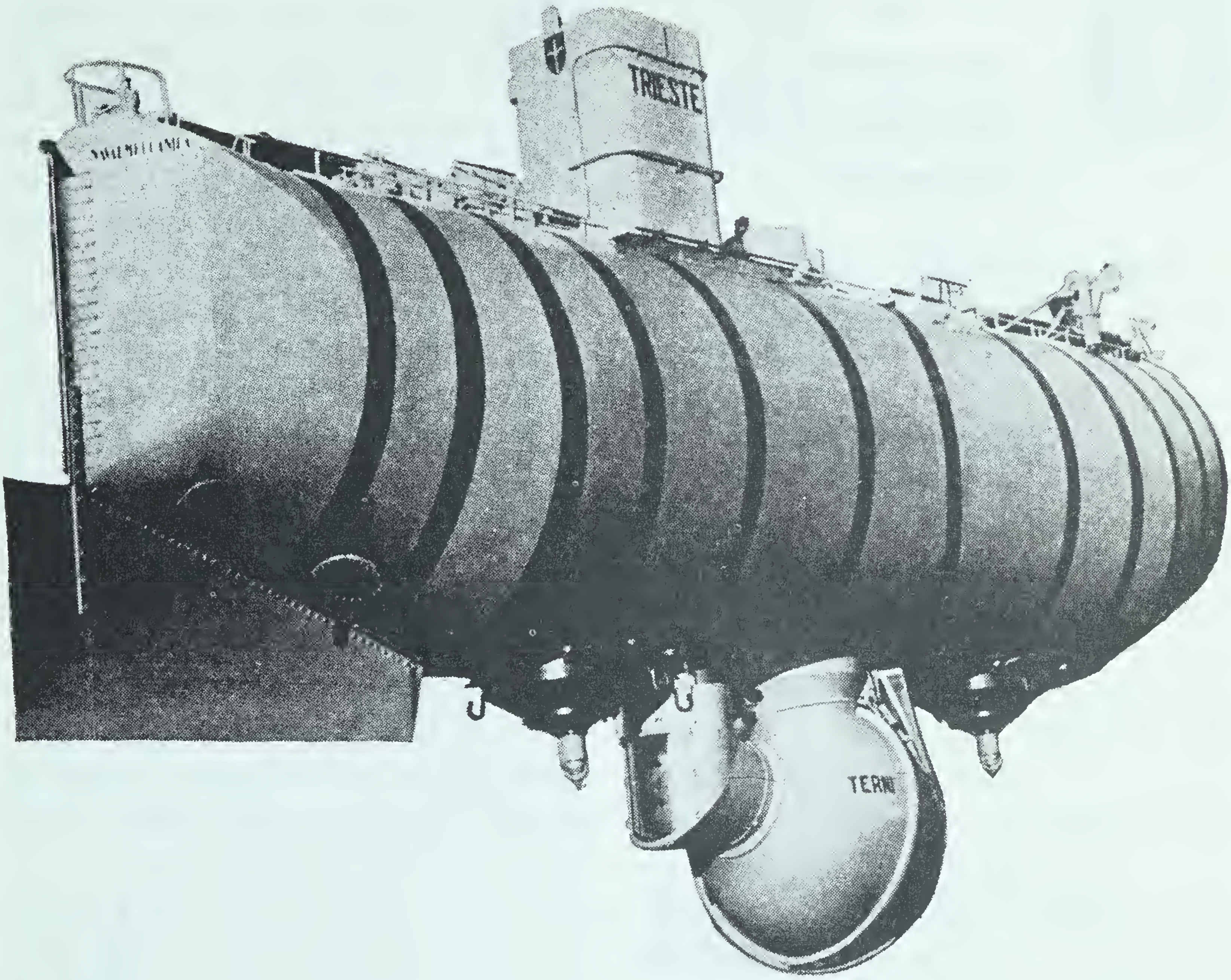


Fig. 7-17. In the bathyscaphe, Piccard made the deepest dive ever attempted by man.

down to a depth of 3,028 feet off the coast of Bermuda, he designed a special structure. He called this a *bathysphere* (*bath*-ih-sfeer). The bathysphere protected his body from the high pressures of about 1,300 pounds per square inch. His bathysphere was built with heavy metal walls and thick windows to withstand this great pressure.

Auguste Piccard, of Swiss descent, invented a similar vessel which he called the *bathyscaphe* (*bath*-ih-skafe). In 1954 he went down 13,283 feet below the surface of the Mediterranean Sea in it.

Scientists can learn about the ocean floor by use of such devices as the bathysphere and the bathyscaphe. They are also able to study the living things at great depths in their natural environment.

REVIEW QUESTIONS

1. Why is it hard to increase the speed of a boat in water? **2.** How do oars move a boat through water? **3.** How does a submarine rise and sink? **4.** How is a submarine propelled while under water? **5.** Why is it difficult for divers to go into deep water? How is it done? **6.** Of what advantage are atomic-powered submarines?

E How can a small force applied to a liquid stop a heavy automobile?

Modern hydraulic machines work on the principle of Pascal's Law. In the 17th Century, Pascal, a French scientist, proved an interesting fact. He filled a small barrel with water and fitted a long tube into a small opening in the top of the barrel. (Fig. 7-18.) He then filled the long tube with water. Even though the actual weight of water in the tube was small, it exerted such great pressure that the barrel burst. Why?

PUPIL ACTIVITY

Get a small rectangular varnish can or similar container. Punch a small hole in the bottom of the can and seal the hole with melted wax. Completely fill the can with water and then quickly push a stopper into the opening at the top of the can. Result?

From this experiment you can see that when you exert pressure on a confined liquid, the pressure is transmitted unchanged through the liquid. We call this principle *Pascal's Law.*

To understand this law better, let us refer to Fig. 7-19. Suppose the area of the piston *ab* is one square inch, and that of the piston *cd* is 1,000 square inches. Then a force of one pound applied to *ab* will act with a force of one pound on each square inch of *cd,* or a total force of 1,000 pounds. By such means the weight of a girl's hand might lift a battleship if the large piston could be made big enough to hold such a ship. In using the hydraulic press shown in Fig. 7-19, the distance the small piston moves is 1,000 times the distance the large piston moves. What is gained in force is lost in distance.

Using Pascal's Law, engineers have devised various machines driven by force applied to water. We call these ***hydraulic*** (high-*draw*-lick) machines because they are operated by the force of water or some other liquid.

In the hydraulic press, pressure is transferred without loss from a small area. The hydraulic press is a machine designed on the principle of Pascal's Law. It is used wherever great force is needed. A hydraulic press is used for such processes as baling cotton, lifting

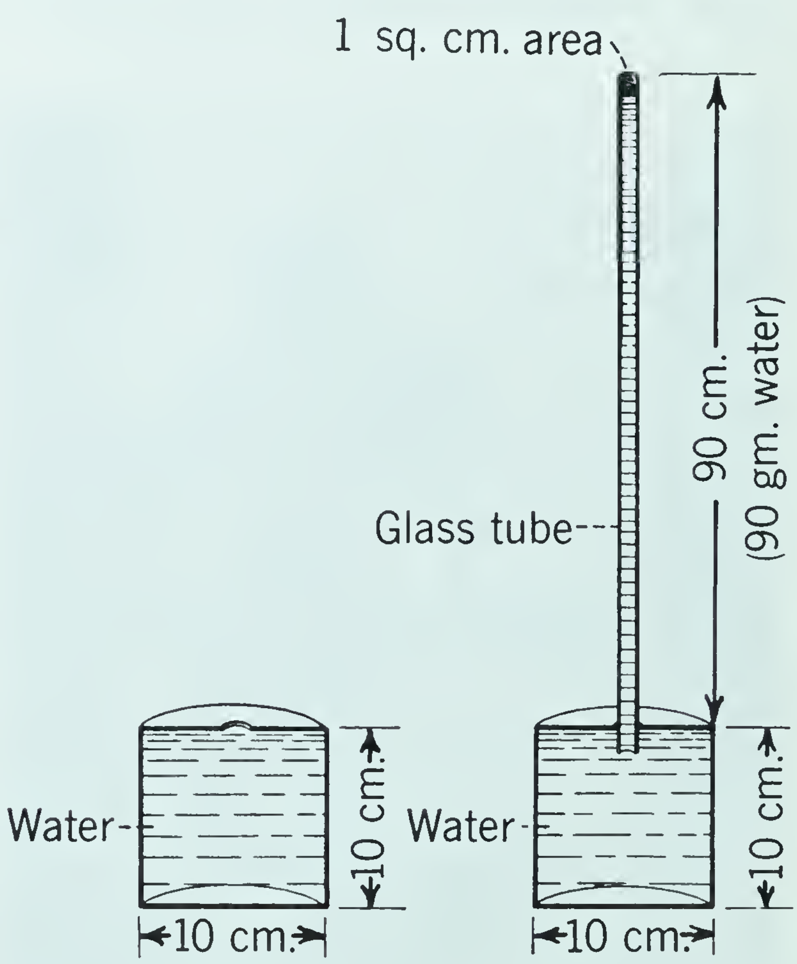


Fig. 7-18. This experiment illustrates Pascal's Law. In exerting pressure on confined liquid, the pressure is transmitted unchanged through the liquid.

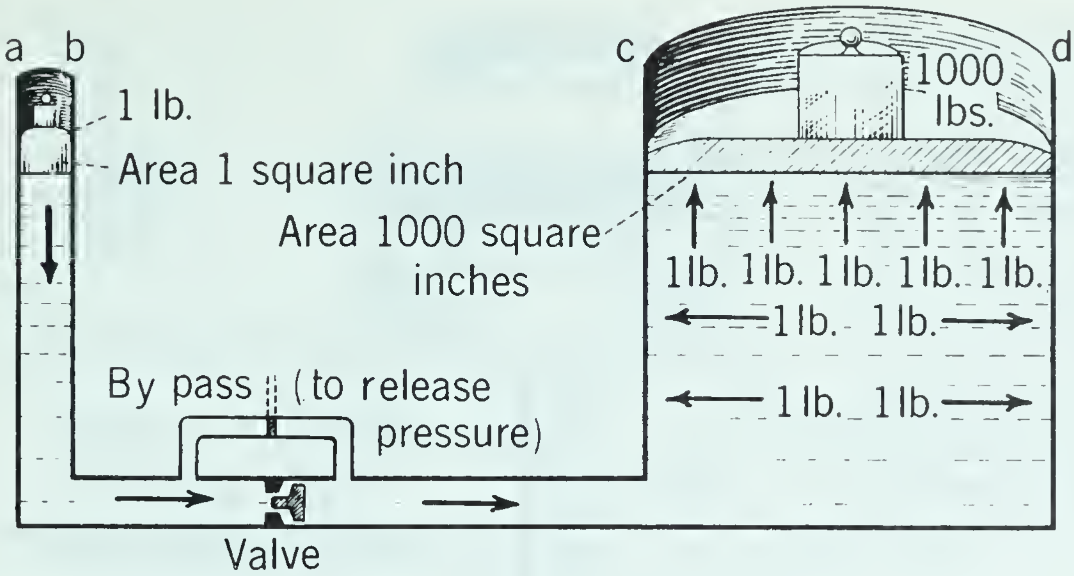


Fig. 7-19. Considerable force may be developed in the hydraulic press by transferring the pressure on a small piston (*ab*) to a large piston (*cd*).

heavy weights, punching holes in steel plates, pressing steel plates into special shapes, and pressing pulp and juices from fruits and vegetables.

There are many variations of this press, but in each case the principle is the same. There is always a small cylinder filled with a liquid. This is connected to a larger one. Each cylinder has a piston fitting it so tightly there is no possibility of any liquid being forced past it. A force, usually from a hand lever or from compressed air, is applied gradually to the piston in the small cylinder. This is then transferred without loss to the piston in the large cylinder. As a result, the large piston is lifted. When the force on the small piston is released, the liquid flows back again and the large piston is lowered.

Hydraulic brakes on automobiles work in the same way. Study the diagram in Fig. 7-20. In this case, water cannot be used since it would freeze in cold weather. Therefore, we use a special fluid which neither freezes nor thickens.

By using the principle of Pascal's Law, hydraulic elevators, hydraulic

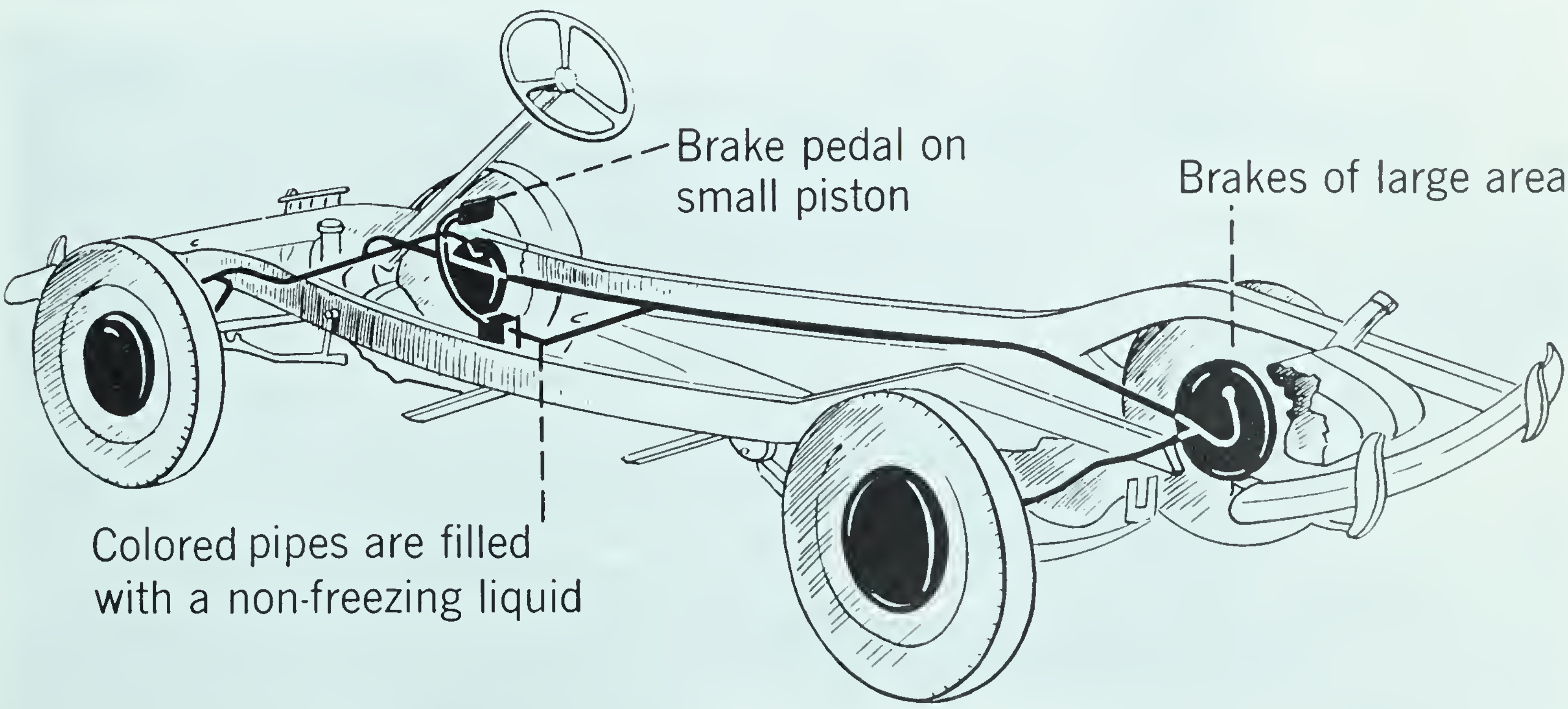


Fig. 7-20. How do the hydraulic brakes on an automobile use the principle of Pascal's Law?

jacks, and automobile hoists used for greasing cars in filling stations have been built. By means of it, also, barber and dentist chairs are raised to the desired height and lowered again. In many hydraulic appliances, oil is used instead of water. Visit your local service station and see how an automobile hoist is used to raise cars for greasing.

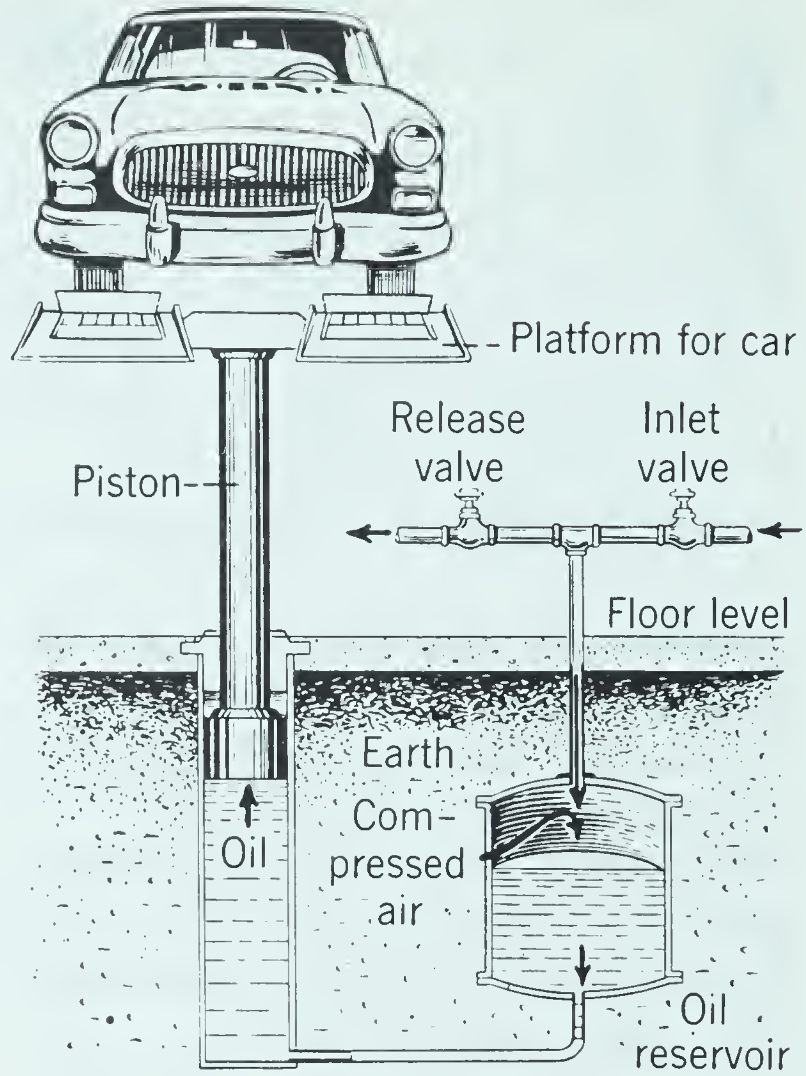


Fig. 7-21. The garage mechanic uses the principle of Pascal's Law to hoist the automobile.

REVIEW QUESTIONS

1. Is water compressible? **2.** If pressure is applied to a confined liquid, what becomes of the pressure? **3.** How is a hydraulic press constructed? **4.** Where is the force applied to a hydraulic press? **5.** Where is the load to be lifted applied in the hydraulic press? **6.** Which moves up and down more rapidly, the large or the small piston? **7.** Why is water not used in the hydraulic brakes of automobiles?

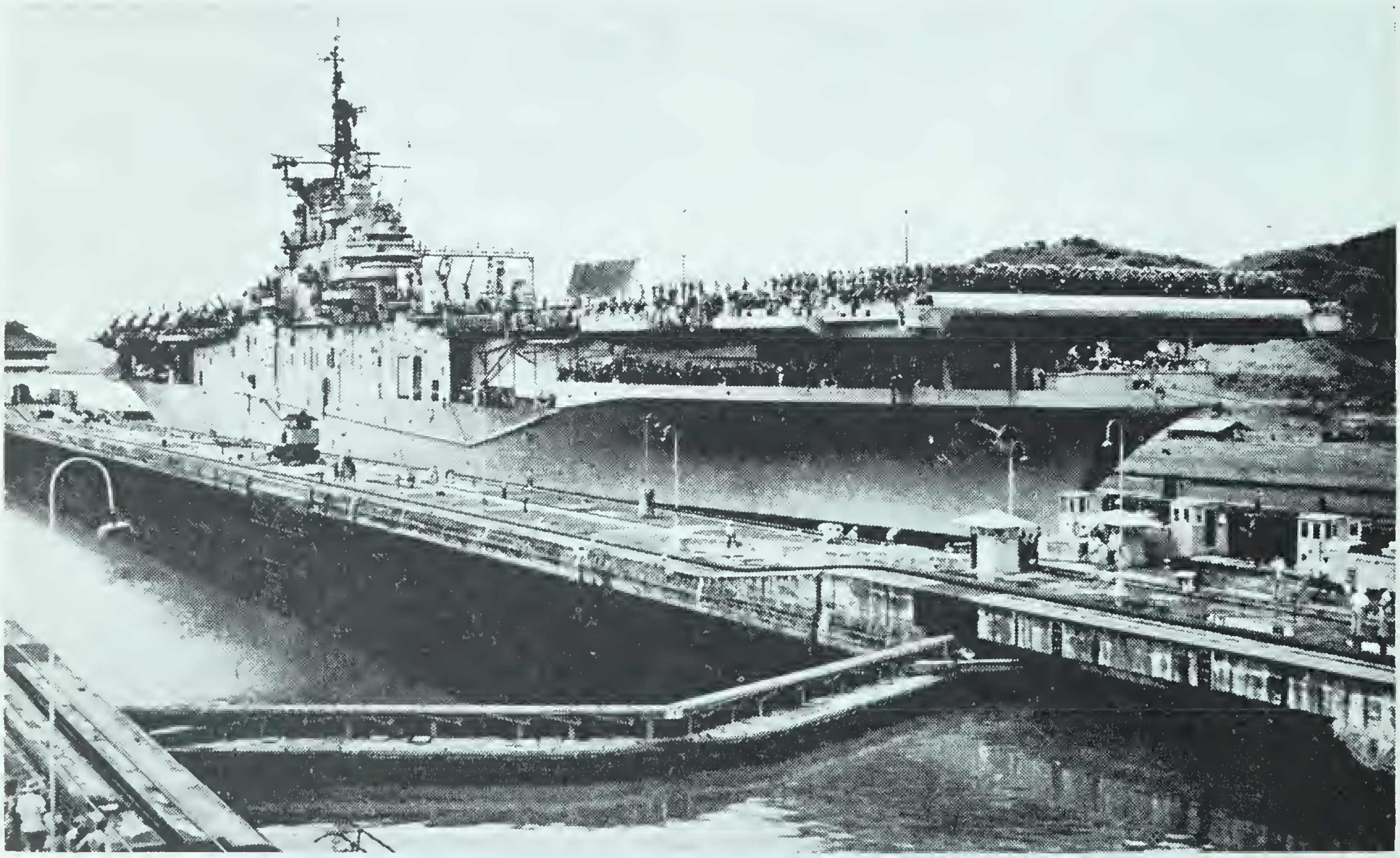


Fig. 7-22. This huge aircraft carrier is easily lifted to a higher level in the Panama Canal as water is pumped into the lock.

QUESTIONS FOR REVIEW AND DISCUSSION

1. What laws were stated by Archimedes and Pascal? When were these laws stated?
2. What were the early forms of travel on water?
3. When was the first water mill built?
4. Why was the invention of the water wheel important?
5. What is the relationship between depth and pressure in water?
6. What do we mean by a ship's displacement?
7. How much water will a block of wood weighing two pounds displace? How much kerosene will this same block of wood displace if it floats?
8. What is the weight of a cubic foot of water? What is the pressure per square inch in water at a depth of one foot?
9. Compare the weight of water displaced by equal volumes of wood and iron.
10. How can objects made of metal be floated?
11. How do water wheels develop force?
12. What is the upward force on an object in water called?
13. Why are dams built? What determines the pressure that can be developed by the water behind the dam?
14. How are submarines and ships alike? How are they unlike?
15. Why do divers have difficulty in going to great depths of water?
16. Under what conditions is a water turbine used?
17. Why can automobiles travel at higher speeds than boats with a motor of the same power?
18. How is it possible to move over water on an aquaplane when the weight of the rider and aquaplane is enough to sink it?
19. How does a swimmer move through water? Why does he float?

SPECIAL REPORTS AND PROBLEMS

1. Report on a visit to the nearest water-power site.
2. Construct a water wheel which will run from the water pressure in the laboratory.
3. Using metal or glass containers as boats, show how these containers can be made to float erect and what factor or factors affect the load which each will support in water.

4. Report on hydraulic brakes.
5. Report on the kinds of water wheels.
6. Report on why divers get the "bends."
7. Report on how tunnels are dug under bodies of water.
8. Report on how sunken vessels are raised.
9. Report on Beebe's explorations in the bathysphere.
10. Report on the use of the aqua-lung by skin divers.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following terms: buoyancy, cylinder, water displacement, hydraulic, dynamo, confined liquid, turbine, piston?
2. What principles of water pressure are provided for in the construction of a dam? Under what kinds of conditions are dams built?
3. In what ways has the development of water power helped man?
4. Should water-power sites be controlled publicly or privately? Discuss.
5. What determines whether an object will sink or float in water?
6. What practical applications are made of the principle that pressure applied to a confined liquid is transmitted equally and without loss in all directions?
7. What are the difficulties in exploring great depths in water? How can we overcome these difficulties?
8. How is a hydraulic press built so that a large resistance can be overcome with a small force?
9. The area of the small piston in a hydraulic hoist is 10 square inches. The area of the large piston is 250 square inches. Neglecting friction, what force must be exerted on the small piston to lift a car weighing 3,000 pounds?
10. Why do all the modern automobiles have hydraulic brakes instead of mechanical brakes?
11. What was the approximate pressure in pounds per square inch on the surface of the bathyscaphe used by Piccard? It went down to a depth of 13,283 feet below sea level.
12. How does adding salt to water affect the buoyant force of the water?
13. If you know the density of an object, and the density of water, how can you use these two facts to determine whether the object will sink or float? Give an example of this.
14. Hydraulic press principles can also be used to gain speed. Catapults are used to give airplanes high speed in leaving an aircraft carrier. Would the airplane be pushed out by the large or small piston? Where is the force applied when the catapults are used?
15. In selecting sites for dams it is important to get a large supply of water back of the dam. Does this large supply of water give more pressure on the dam? Does it provide a more continuous supply of water? Is rainfall uniform at all seasons of the year? Is this the reason for a large storage supply?

The old

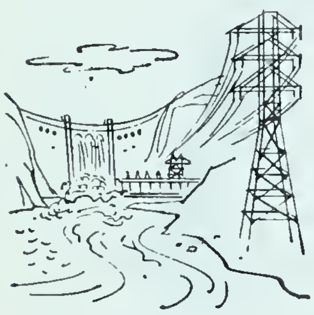
DID EARLY MAN UNDERSTAND THE PRINCIPLES OF FLOATING and sinking as we understand them now? How did he propel boats through the water? How did he use the force of falling water?

The first boats were crude and small. They moved slowly and could only go short distances. This was because they were propelled by hand. Early man made little use of the force of running water.

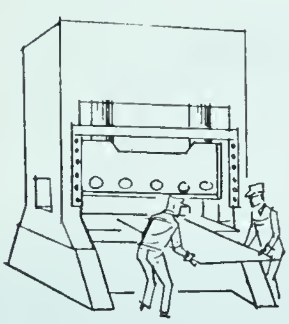
About fifty years ago few people realized that the force of running water would furnish electric energy for so many uses. One hundred years ago man made little practical use of the principles of hydraulics.

The new

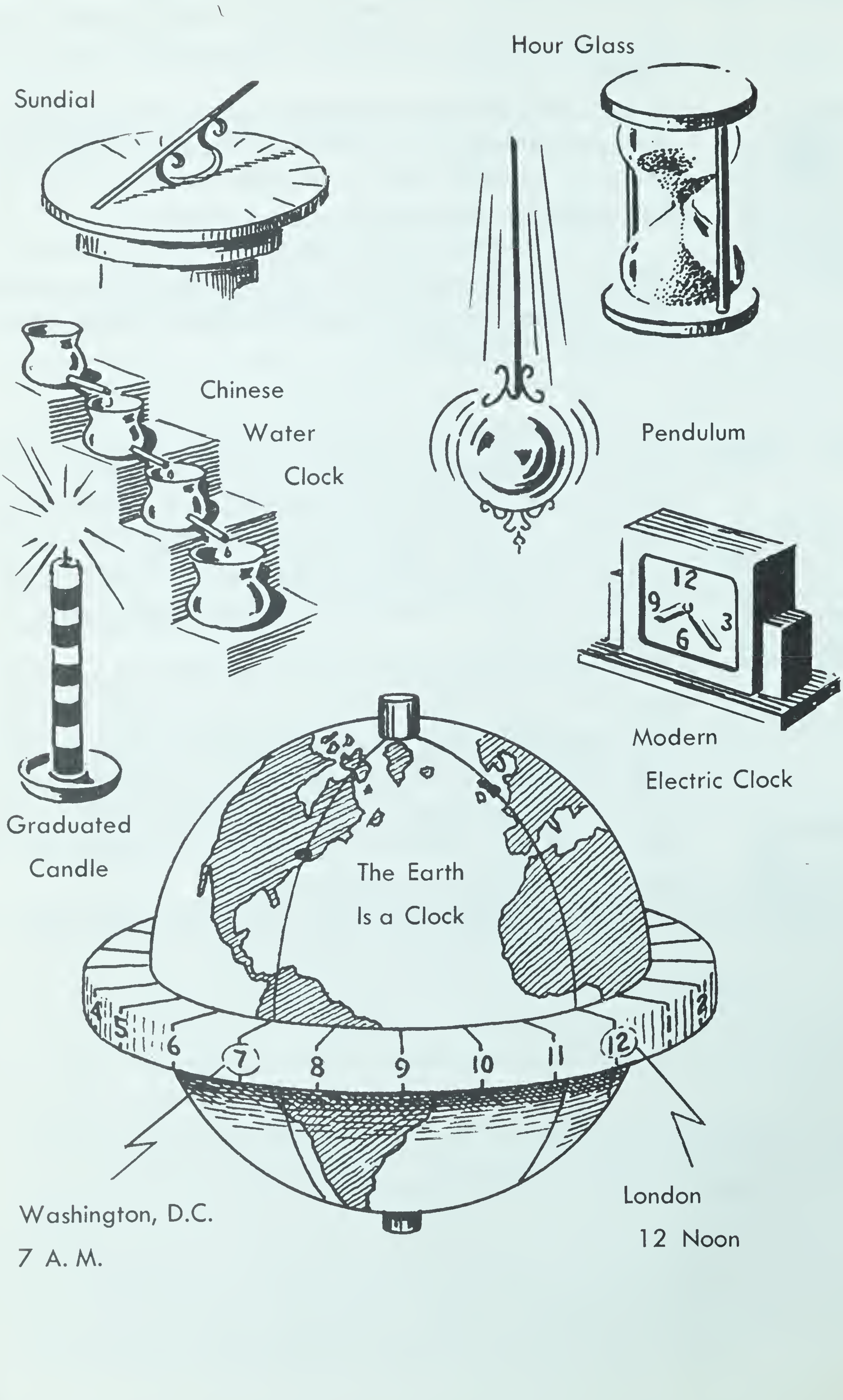
TODAY OUR SHIPS ARE LARGE AND COMFORTABLE. MECHANICAL power propels them rapidly, and they can travel to all parts of the world. Our submarines move not only under water, but also on the surface. They dive to escape danger or to approach a target. They can travel under water for hours at a time. Atomic-powered submarines can stay under water for an indefinite period.



Electric energy lights and heats our homes today, runs railroad trains, and supplies energy to factories. We have learned that water pressure can do many things. By applying the principle of hydraulics, we can stop a heavy automobile or raise it on a platform to grease it. We can lift heavy objects which are used in factories. Sections of automobile bodies are shaped from sheets of steel on hydraulic presses.



These are only a few things which man has learned from his discoveries about the forces of water.



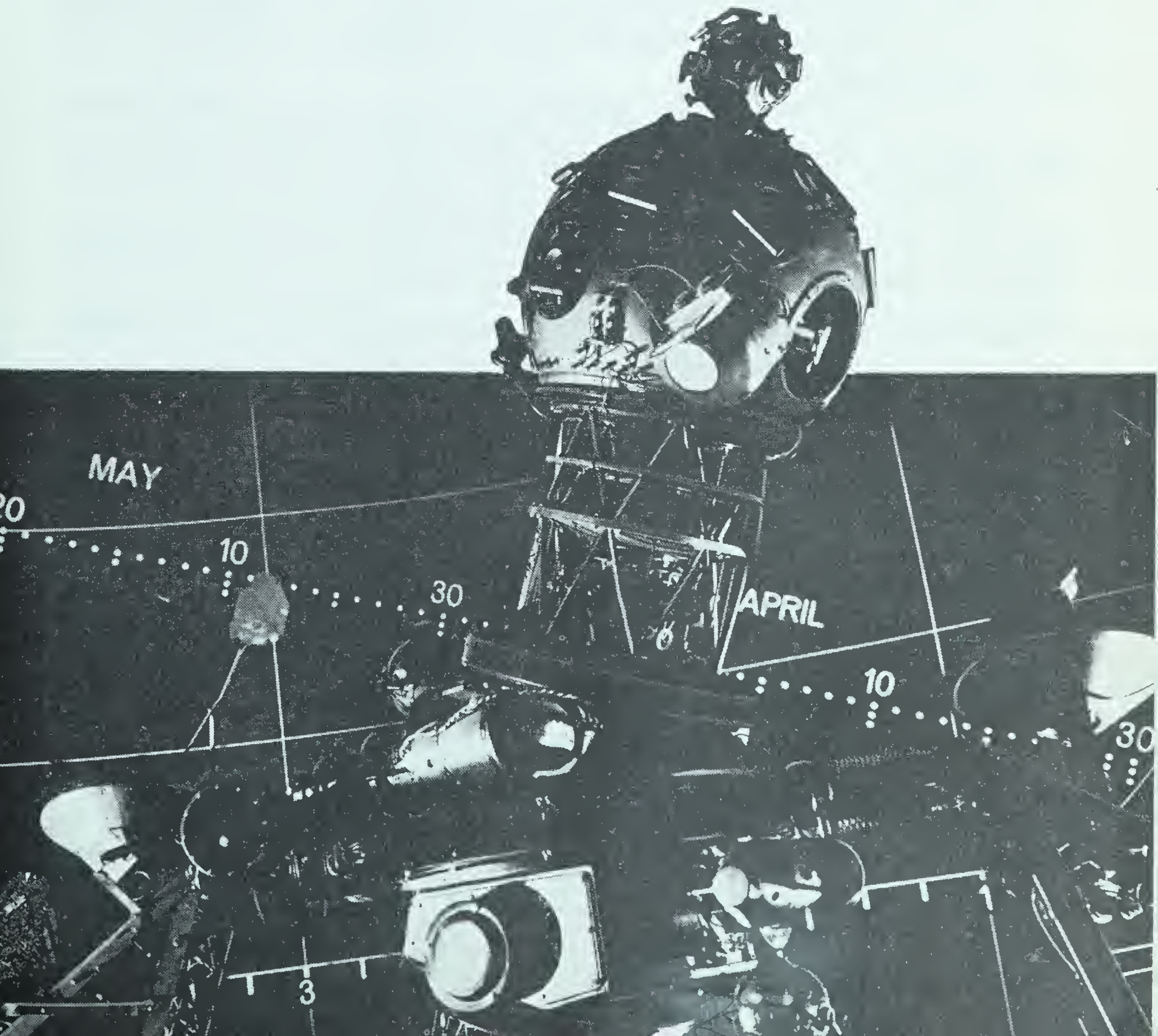
Hour Glass
Sundial
Chinese
Water
Clock
Pendulum
12
9
3
6
Modern
Electric Clock
Graduated
Candle
The Earth
Is a Clock
4
5
6
7
8
9
10
11
12
Washington, D.C.
7 A. M.
London
12 Noon

UNIT 8

How has man learned about space and the heavenly bodies?

DISCOVERY AND PROGRESS

PROBABLY the first people to study the sky were the early shepherds watching their flocks at night. Sometimes they saw a shooting star, which we know today as a *meteor*. As they watched, they noticed changes in the sky picture. These changes were due to movements of the moon and planets, and what looked to them like movements of the sun and stars.



Shepherds saw the sun rise and set, causing day and night. Now we know that the rotation of the earth brings day and night. They saw what seemed to be changes in the shape of the moon. We call these changes ***phases.*** They also knew how long it took for the moon to pass through all its phases. And they believed that each full moon was actually a new and quite different one. The period from one full moon to the next one was called a ***moon.*** We call it a ***month.***

The early people knew little about the heavens so they made up stories about stars and planets. They named them after heroes, friends, and animals.

The Big Dipper was known as the Great Bear. The Little Dipper was the Little Bear. The large W of stars they named Woman in the Chair (Cassiopeia) because it looked like a chair. Hercules and Orion, mighty hunters, also had places in the heavens.

Thales, the Greek *astronomer* (one who studies the skies), believed that the earth was round. He thought also that the moon's light was reflected from the sun, and that the stars gave out their own light. Another Greek astronomer, Aristarchus (ar-is-*tar*-kus), discovered the length of the year, and decided that the earth moved around the sun. Then the Egyptian scientist Ptolemy (*tol*-em-ee) declared that the earth was the center of the universe. He said the sun, moon, and planets moved around it. He knew 48 groups of stars; today we know more than 80.

The Italian scientist, Galileo (gal-ih-*lay*-oh), was the first astronomer to use a telescope. He studied the sky night after night. He also is credited with the invention of the pendulum as well as the pendulum clock.

Gilbert, an Englishman, who lived about the same time as Galileo, proved that many of the old ideas about the compass were wrong. The Chinese and Arabs had used this instrument for centuries, but they did not know why it worked. Gilbert proved that the earth was like a magnet with poles. And he used the scientific method to explain the real action of the compass to find direction.

Early man used the sun to tell time and based the sun dial on the position of the sun. Then came many varieties of hour glasses and finally the pendulum clock was invented.

Just as the modern clock has become the ordinary way to tell time, so the compass is the usual way to tell direction. It has undergone many improvements and can be used under almost any conditions of weather and climate.

Scientists will not be satisfied until they have discovered the exact nature and composition of the heavenly bodies. They also want to know what keeps them moving as they do. Much still needs to be learned.

The photograph on page 201 shows the projector in a large planetarium. It is used to throw images of star constellations and other heavenly bodies on the darkened ceiling dome in imitation of the night sky.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What are the types of heavenly bodies in the solar system? **2.** How do the planets move around the sun? The moon around the earth? **3.** What causes day and night? The seasons? **4.** What are constellations? **5.** What are the reasons for believing that the earth is round? **6.** If you were lost in the woods, how could you tell direction if you had a watch? **7.** Why does a compass needle point north and south? **8.** Why does a compass needle not point true north? **9.** What do we mean by latitude? **10.** In what longitude does your town lie? **11.** How do travelers tell direction at night? **12.** How do travelers locate their position on the earth's surface? **13.** Will man ever travel in space?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

centrifugal force . .	(sen-*trif*-you-gul), a force which is directed outward when an object moves in a curved path.
constellation	(kon-stel-*lay*-shun) a group of stars forming some kind of pattern or figure.
declination	(deck-lin-*ay*-shun), the variations of the N pole of the magnetic needle from the true north-south line.
eclipse	the event when the moon passes between the sun and the earth, or when the moon enters the earth's shadow.
equator	an imaginary circle around the earth, equidistant from the two poles.
latitude	distance in degrees measured north or south of the equator.
light year	the distance light travels in one year, or six trillion miles.
longitude	the distance in degrees east or west of the prime meridian running through Greenwich, England.
magnitude of a star	referring to the brilliancy of stars.
meridian	(mer-*ih*-dee-an), an imaginary line on a map or globe passing through the North and South Poles.
planet	a large heavenly body which revolves around the sun, and reflects the light of the sun.
satellite	(*sah*-tel-lyte), a body revolving around a planet.
solar system	the sun and the heavenly bodies revolving around it.

A What are the heavenly bodies in the solar system?

Astronomy deals with a study of the bodies in the sky. When you look at the sky on a clear night, there are many objects to see. You may wonder how man has learned to identify them all. But during the day it is quite different. Then you see only the sun and occasionally the moon. *Astronomy* (as-*tron*-oh-mee) is that branch of science which studies the heavenly bodies: the sun, moon, and stars. Astronomers map, classify, and describe these heavenly bodies.

We call the sun and all the bodies which revolve around it, the solar system. A *planet* is a large body which revolves around the sun and does not produce its own light and heat. There are nine planets, including our earth. Many of these planets have *satellites,* or moons revolving around them. A *satellite* (*sah*-tel-lyte) is any body revolving around a planet. Other members of the solar system are meteors, comets, and asteroids. The sun is a star. It is the star nearest the earth. All stars produce their own light and heat.

The sun's surface is very hot. Astronomers have estimated that its outer surface is between 6,000° and 10,000° F. Its diameter is about 864,000 miles, and its volume is about a million times that of the earth. Astronomers tell us that it is a mass of very hot gases. This is because no chemical elements can exist in the solid or liquid form at the high temperatures found on the sun.

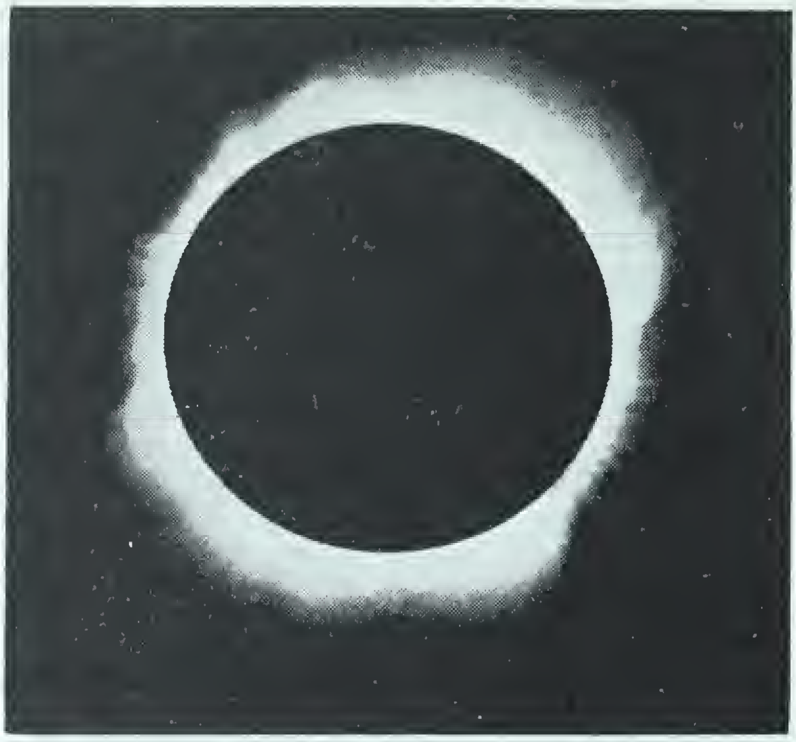


Fig. 8-1. The lighted vapors, which you see here, form the sun's corona. It can normally be seen only during an eclipse of the sun.

The lighted vapors from the sun form its *corona* (kaw-*roh*-nah). This is a band around the sun extending millions of miles beyond it. However, we can only see this corona when the moon passes between the sun and the earth. When this event occurs, we call it an *eclipse* of the sun. As you can see in Fig. 8-1, the sun's corona is clearly visible during an eclipse.

Astronomers estimate that the sun is continually furnishing the earth with about one-quarter million horsepower for each person. Of this huge total, not more than one-thousandth part is stored in fuels and foods and in falling water.

The sun is the center of the solar system. There are nine planets that revolve around the sun (see Fig. 8-2). The planets are spherical masses much

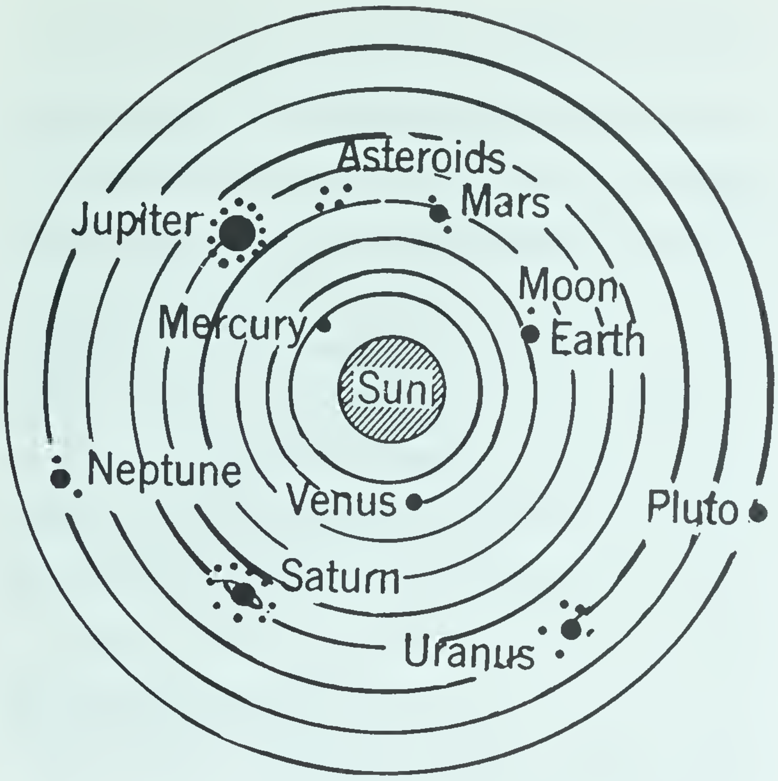


Fig. 8-2. The nine planets which revolve around the sun move in a counter-clockwise direction.

like the earth in composition and movements. They are the only heavenly objects on which any known form of life can possibly exist. However, so far as science can tell at the present time, the earth is probably the only planet which does support life.

The nine planets in the order of their distance from the sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

Some characteristics of the planets. *Mercury* is the smallest and is closest to the sun. One side of it always faces the sun and that side must be extremely hot. The side away from the sun is always in a shadow and has a temperature about the same as that of dry ice. Mercury has no satellites.

Venus is about the size of the earth. It is, however, always clouded by a dense fog. The reason it appears as the brightest of all the planets is because of its nearness to us and because its atmosphere reflects more light than any other. It has no satellites, either.

Mars is a brilliant planet. It is surrounded by a thin atmosphere. In fact, astronomers can see its brick-red outer surface with a telescope. It has very little oxygen and water. Noon temperature is about 50° or 60° F. Mars gets much less than half as much heat

	Diameter in miles	Approximate distance from sun in miles	Length of year	Length of day compared to earth	Number of moons
MERCURY	3,200	36,000,000	88 days	88 days	0
VENUS	7,848	67,000,000	225 days	30 days	0
EARTH	7,927	93,000,000	365 days	24 hours	1
MARS	4,268	142,000,000	687 days	24 hours	2
JUPITER	89,329	483,000,000	12 years	10 hours	12
SATURN	75,021	886,000,000	29 years	10 hours	9
URANUS	33,219	1,782,000,000	84 years	11 hours	5
NEPTUNE	30,917	2,793,000,000	165 years	16 hours	2
PLUTO	3,600	3,670,000,000	248 years	?	?

energy as our earth does. Some astronomers believe that there may be life on Mars; others say there cannot be. Actually, no one really knows.

Jupiter is larger than all the other planets combined. It makes one complete turn on its axis in less than ten hours and you can see it either in the morning or evening. It is so far from the sun that its surface must be extremely cold. It has 12 satellites or moons.

Saturn is the familiar planet with the rings around it. These are about ten miles thick, but to an astronomer, they appear very thin. The atmosphere on this planet is very cold.

Uranus and *Neptune* are far away from the sun and are also very cold. Uranus has five satellites, while Neptune has only two. *Pluto* was the last planet to be discovered and we have little information about it.

The table on page 205 gives the approximate size, distance from the sun, length of year, length of day, and number of satellites of the planets.

The moon revolves around the earth. Of all the heavenly bodies, the moon is nearest the earth being about an average of 240,000 miles away. But it is smaller than our earth. Its diameter is only 2,160 miles. The moon has no atmosphere nor any water. It has high mountains and deep valleys. Because there is no water the rocks have not been worn down to form soil. Scientists believe there is no life on the moon, because there is no atmosphere.

The moon revolves around the earth in a counterclockwise direction. It takes about 28 days to make one revolution. Because the same side is always turned toward the earth we see only this one side. The temperature of the part of the moon facing the sun is over 200° F. On the shaded side the temperature may be 200° F. below zero. These temperature differences

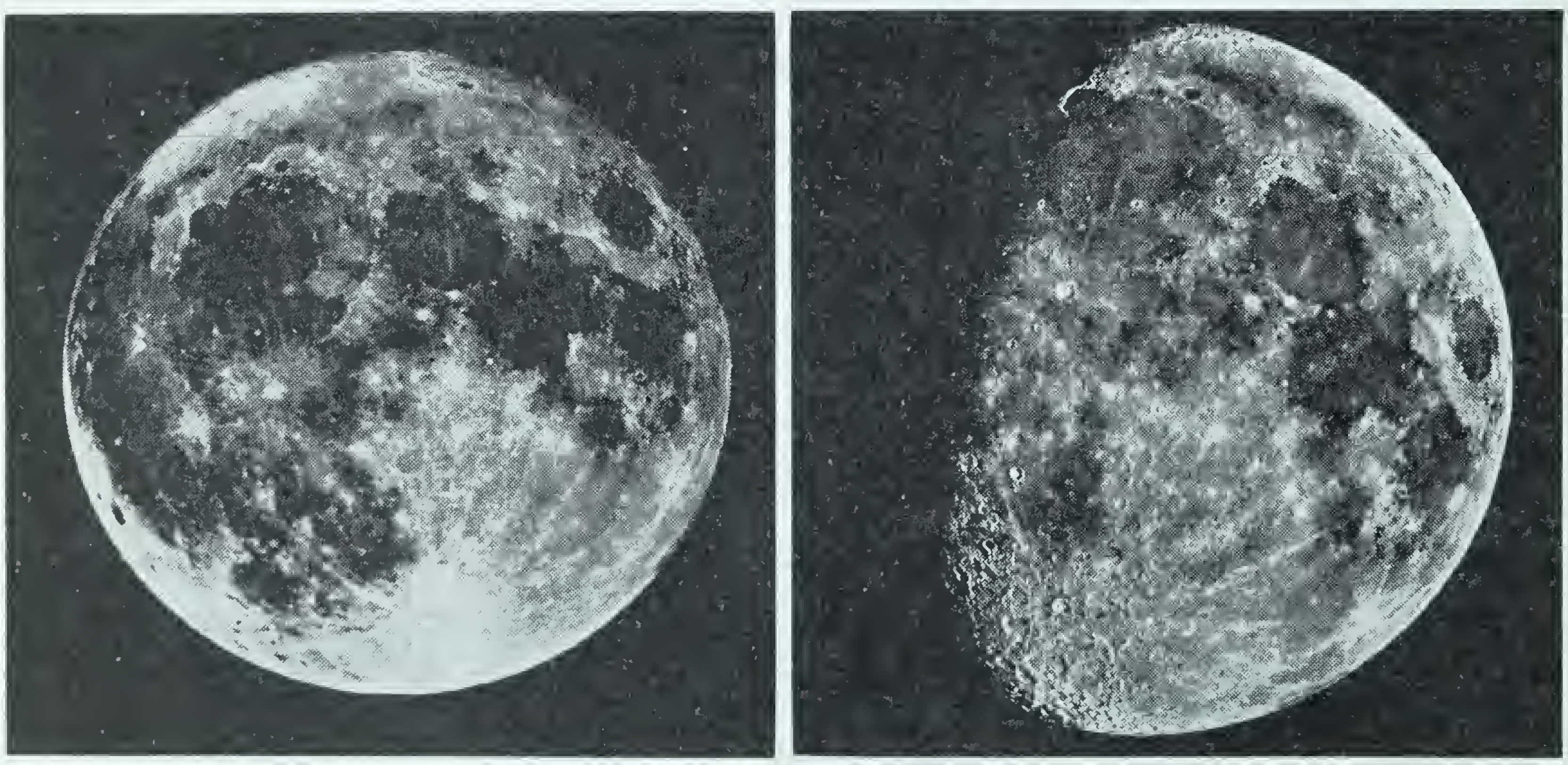


Fig. 8-3. The left photograph shows a full moon, while the one on the right shows the moon in the 10th day of its cycle. Notice the markings.

are due to the lack of atmosphere on the moon, and to its slow rotation.

The moon reflects light to the earth. Because it changes its position relative to the sun, it passes through several phases which we know as new, first quarter, full, and third quarter. The diagram in Fig. 8-4 gives the positions of the moon as it revolves around the earth. It also shows how the moon appears to an observer on the earth.

DEMONSTRATION

Darken the room. Using a strong light such as a 100-watt lamp, stand several feet from the source of light. Have someone revolve a metal ball around the source of light, with the same side of the ball facing the light at all times. What part of the ball reflects light to you as the observer?

From this demonstration, you should be able to understand why the moon apparently changes its shape during any month.

Meteors are small bodies that become visible when they enter the earth's atmosphere. These solid planetary bodies consist of rock, iron, and nickel. They start burning as soon as they reach the air, so appear to be tiny balls of fire. Most of them are completely burned before they reach the earth. Sometimes we call them *shooting stars* because they dart through the sky at such terrific speeds.

Occasionally, a few of the larger meteors land on the earth's surface without being completely burned. We call these remnants of the original meteors *meteorites* (*meet*-ee-oh-rites).

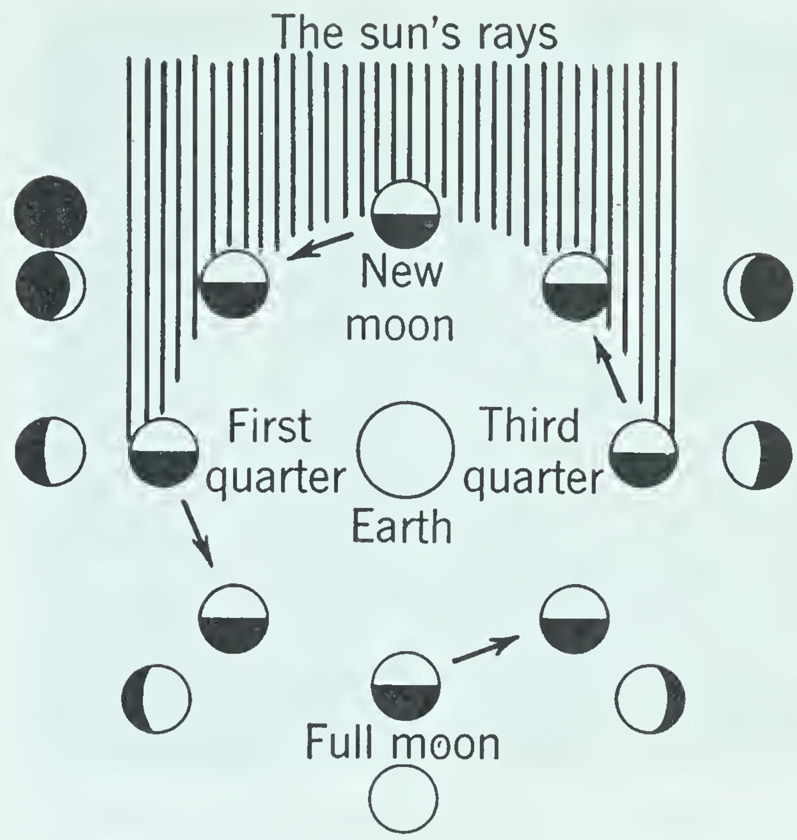


Fig. 8-4. The inner circle shows the positions of the moon as it revolves around the earth. The outer positions show the moon as it appears to you on the earth.

Comets are large bodies composed mostly of gaseous matter. Apparently, they revolve around the sun in regular paths. Comets have a bright head and a long tail which always points away from the sun. Their paths sometimes bring them into our range of vision, usually at regular intervals. Halley's comet is the most famous and appears every 75 years.

The *asteroids* are tiny planets whose paths of revolution around the sun lie between the orbits of Mars and Jupiter. More than 1,500 of these have been discovered. Some of them are a few hundred feet in diameter. The largest known asteroid has a diameter of 480 miles.

REVIEW QUESTIONS

1. What is the solar system? **2.** What are the characteristics of the sun? **3.** What is a planet? A moon? **4.** What

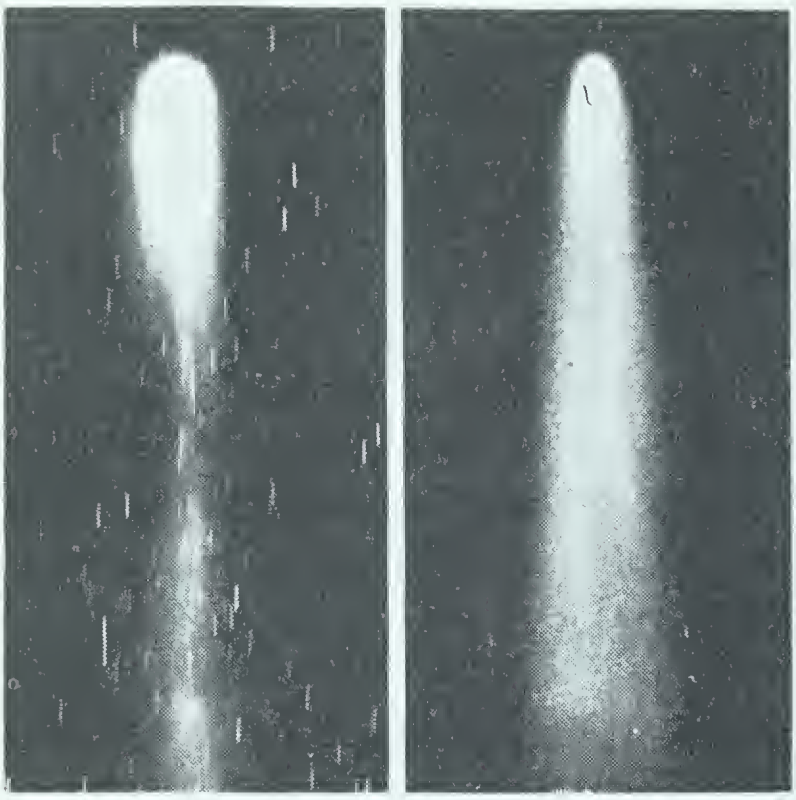


Fig. 8-5. These pictures show Halley's comet as it was photographed during its last appearance in 1910. When may we expect to see it again?

planet is nearest the sun? Farthest away from the sun? **5.** Why are some planets so much hotter than others? **6.** What are the characteristics of the moon? **7.** In what direction do planets revolve around the sun? The moon around the earth? **8.** What are meteors? Meteorites? Comets? Asteroids?

B What are some of the problems of space travel?

One problem of space travel is that of having enough oxygen. You know that everyone needs oxygen in the air he breathes. You also have learned that the air becomes thinner as one goes away from the earth's surface. All airplane pilots carry a necessary supply of oxygen with them when they fly at high altitudes. Now what about the prospects of travel in outer space?

Man must take along a supply of oxygen if he plans to remain in space for any length of time. This would probably be kept in steel tanks under pressure. He would also need an apparatus to remove impurities from the air he exhaled. Then the same air could be reused.

Another problem of space travel is air pressure. As you know, you live at the bottom of the atmosphere where the air pressure is about 15 pounds per square inch. As you rise to higher altitudes the air pressure becomes less, and breathing becomes more difficult. If you continued going up, you would finally reach a point where breathing would be impossible. There are two possible solutions to this problem. The first would be to build space ships with pressurized cabins to maintain almost normal air pressure. This method is used today in airplanes that fly in the stratosphere. The second solution is to provide pressurized suits for each space traveler. Experimental space suits are even now in use by the pilots of jet-and-rocket-engined airplanes. See Fig. 8-10, page 212.

Probably the space man of the future will travel in a pressurized ship, wearing a space suit as a precaution against a possible "blow out." It is estimated that man could live only about 15 seconds in space if he were to lose accidentally his pressurized environment.

The earth's gravity and the inertia of the space ship must be overcome to make journeys into space. If you throw a ball up into the air, it falls to earth again quickly. The harder you throw it, the farther it rises before it

falls back. Scientists estimate that a speed of 25,000 miles per hour would be required to break away completely from the earth's gravity. In the spaceman's language, this is called "the

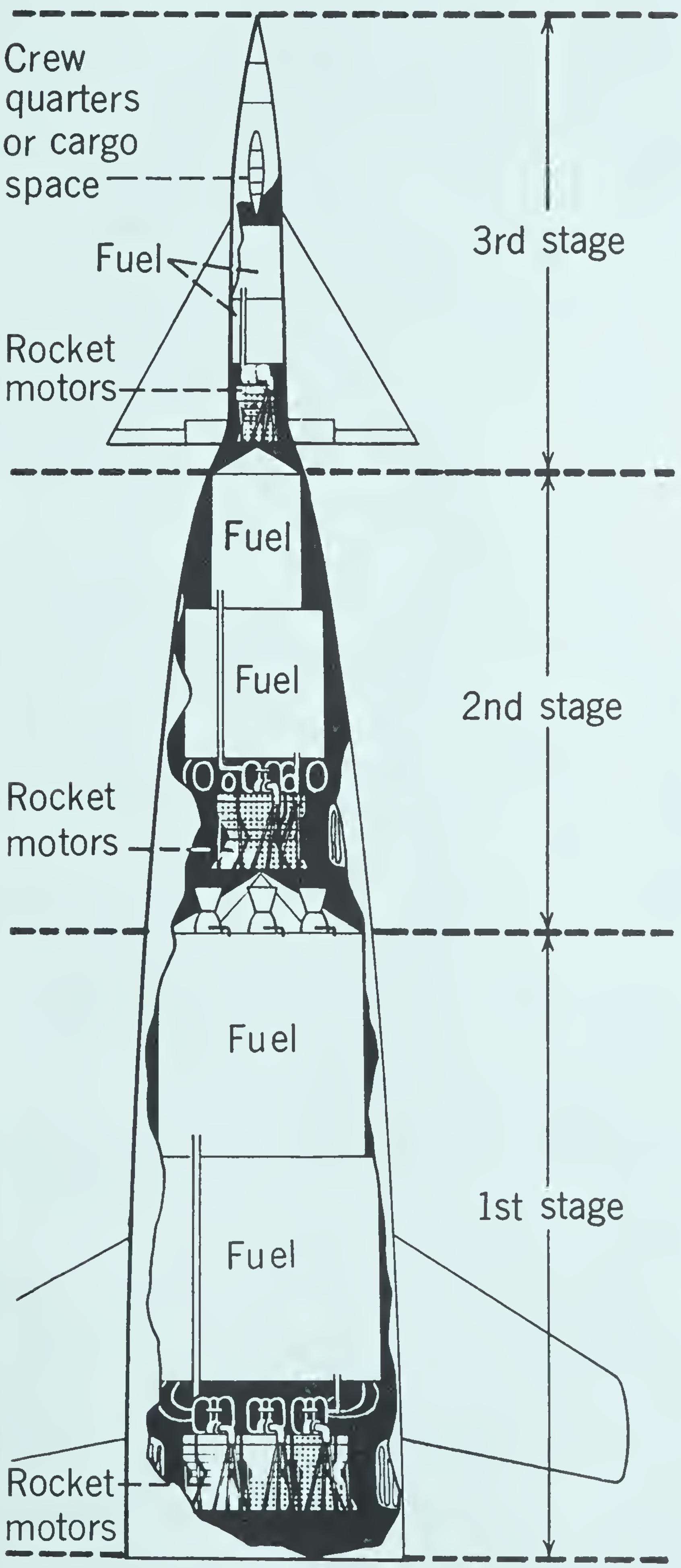


Fig. 8-6. Scientists think that by building a space ship in three stages, great energy speeds can be achieved for it to escape from the earth's gravity.

velocity of escape." However, it is calculated that a speed of only 18,000 miles per hour would be sufficient to maintain a space ship in an orbit around the earth. This would be just outside the earth's atmosphere. You might call such a space ship an *artificial satellite,* since it would keep its orbit indefinitely just as the moon keeps its orbit.

Rockets will furnish the power to drive a space ship. Calculations show that it will be practical to achieve speeds great enough to escape from the earth's gravity by building the space ship in three or more stages (see Fig. 8-6).

The first stage would be the base of the ship. After its fuel was used up, the first stage would be automatically released. The second stage would then drive the ship to a still greater speed and in turn be released. Fig. 8-7 shows an artist's idea of what this might look like. By this time the ship would be traveling at the speed of about 14,000 miles per hour. The third stage would then give the added speed to achieve a circular orbit. It is not likely that a three-stage rocket could reach the velocity of escape.

Another problem for the space traveler is the matter of acceleration. *Acceleration* (ak-sel-uh-*ray*-shun) is the rate of change of speed. You know how you are pressed against the back of the seat by inertia when an automobile suddenly picks up speed. Imagine the force to which you would be subjected if the automobile could accelerate to a speed of 14,000 miles per hour in about four minutes! Yet this is the acceleration which scientists

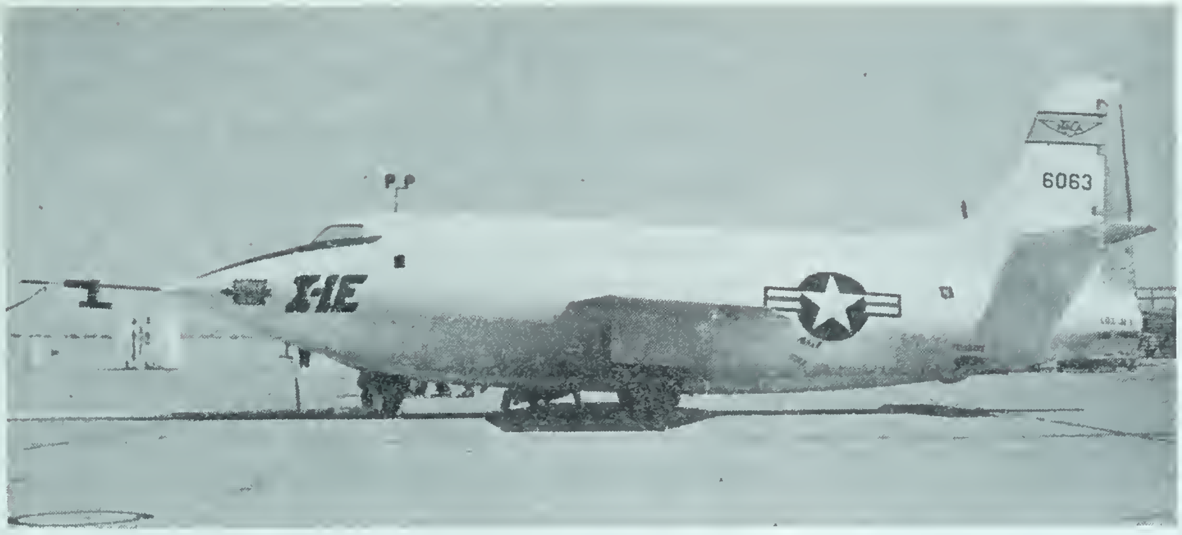


Fig. 8-8. Here you see an experimental rocket plane. Compare it to what a future space ship might look like as shown in Fig. 8-7.

estimate that the first two stages of a space rocket would achieve. Experiments made by test pilots show that man can stand these accelerations.

One testing device is a human *centrifuge* (*sen*-trih-fuge) which whirls a person around at very high speeds, several hundred miles an hour. Another is a *rocket sled* which accelerates in exactly the same way a rocket ship would. The force of acceleration is measured in units called *g*'s. One *g* is the force that gravity alone exerts on an object, equal to its weight. Calculations indicate that the first stage of a rocket would burn for about 1½ minutes, with an acceleration of 9 *g's*. The second stage would last for about 2 minutes and give an acceleration of 8 *g*'s. The third stage would be much shorter, lasting just one minute with an acceleration of only 3 *g*'s.

Actual experiments show that a healthy man can withstand accelerations of 14 *g*'s or more, provided he is lying down. Seated, he "blacks out" at about 6 *g*'s because his heart cannot pump blood to his brain against the extreme force of acceleration.

Fig. 8-7. A space ship drops one of its stages, which will fall harmlessly into the sea. (Adapted from *Worlds in Space* by Martin Caidin.)

A rocket ship would be weightless in space once its fuel had burned because it would not be accelerating. Everything inside the ship would also be weightless. This problem of weightlessness or zero gravity will probably bother men greatly. However, actual tests on mice and monkeys in experimental rockets show no serious aftereffects on short flights into space.

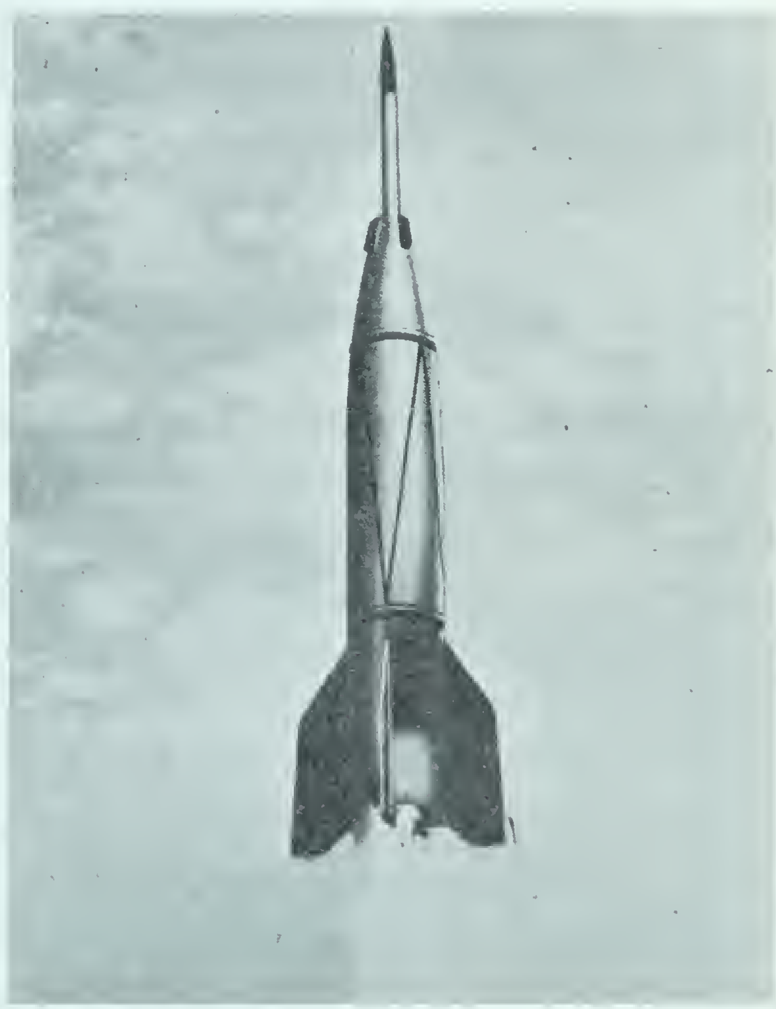


Fig. 8-9. An experimental rocket, such as might be used to launch the first unmanned space ship, is shown here.

Fig. 8-10. This first full pressure flight suit was successfully demonstrated at an altitude of 70,000 feet.

When you dive from a springboard or drop rapidly in an elevator, you get just a brief sensation of the weightless condition. Scientists believe that a person in space will probably feel the sensation of continually falling until he finally becomes accustomed to weightlessness.

Radiations in space will be dangerous. Penetrating ultra-violet rays from the sun will cause serious and even fatal burns unless the space traveler is well protected. The earth's atmosphere protects us earth-dwellers from the effects of ultra-violet radiation to a considerable degree. Nevertheless, even here on earth we sometimes get a bad sunburn if we stay out in the sun's direct rays too long. The space man will also be exposed to the penetrating cosmic rays. These cosmic rays are similar to powerful X-rays and atomic radiations, which are much stronger in outer space than on earth's surface.

Meteorites are another space problem. These very seldom land on earth because the air burns them up long before they penetrate the atmosphere and fall to the ground. In space, with no protective layer of atmosphere, a meteorite might cause great damage if it hit a space ship. However, astronomers calculate that the danger of a large meteorite hitting a space ship is very slight.

Temperature will present still another serious problem in space travel. Rapid acceleration will generate considerable heat of friction between the space ship and air. This is even now a problem with modern jet and rocket aircraft. Once out in space, there will be no air to heat the ship by friction. However, any part of the space ship exposed to direct sunlight will be heated above the boiling temperature of water. The side away from the sun will have a temperature well below zero.

How will man conquer space? We have considered the major problems that must be solved if man is to travel successfully in space. Now let us see how man can overcome the known obstacles and eventually reach the moon and planets.

Man has learned something about space travel in flying rocket and jet planes. In fact, you might say that modern rocket planes such as the X-2 (see Fig. 8-8) are already space ships in some respects. The facts learned from them about the problems of oxygen, air pressure, acceleration,

and temperature will be useful in planning true space travel.

The first space ship will probably be a small unmanned satellite. It will be packed full of recording devices, with a radio transmitter to send back its readings to observers on the earth. Such a satellite is already in the planning stage, and may be in its orbit by 1957 or 1958. From it we will get information about space that will be of great value in the planning of larger space craft. We already have rockets capable of putting this experimental satellite into an orbit a few hundred miles above the earth's surface.

A manned space ship would be the next logical step. It will probably be a four-stage rocket. The last stage will be built with a double-walled pressurized cabin to carry the crew of about 4 to 6 men. It will have wings with control surfaces, much like the present rocket plane shown in Fig. 8-8. It is likely that this first manned space ship will be sent into an orbit so that it circles the earth a few hundred miles up. It will be used for observations which could not be made from an unmanned satellite.

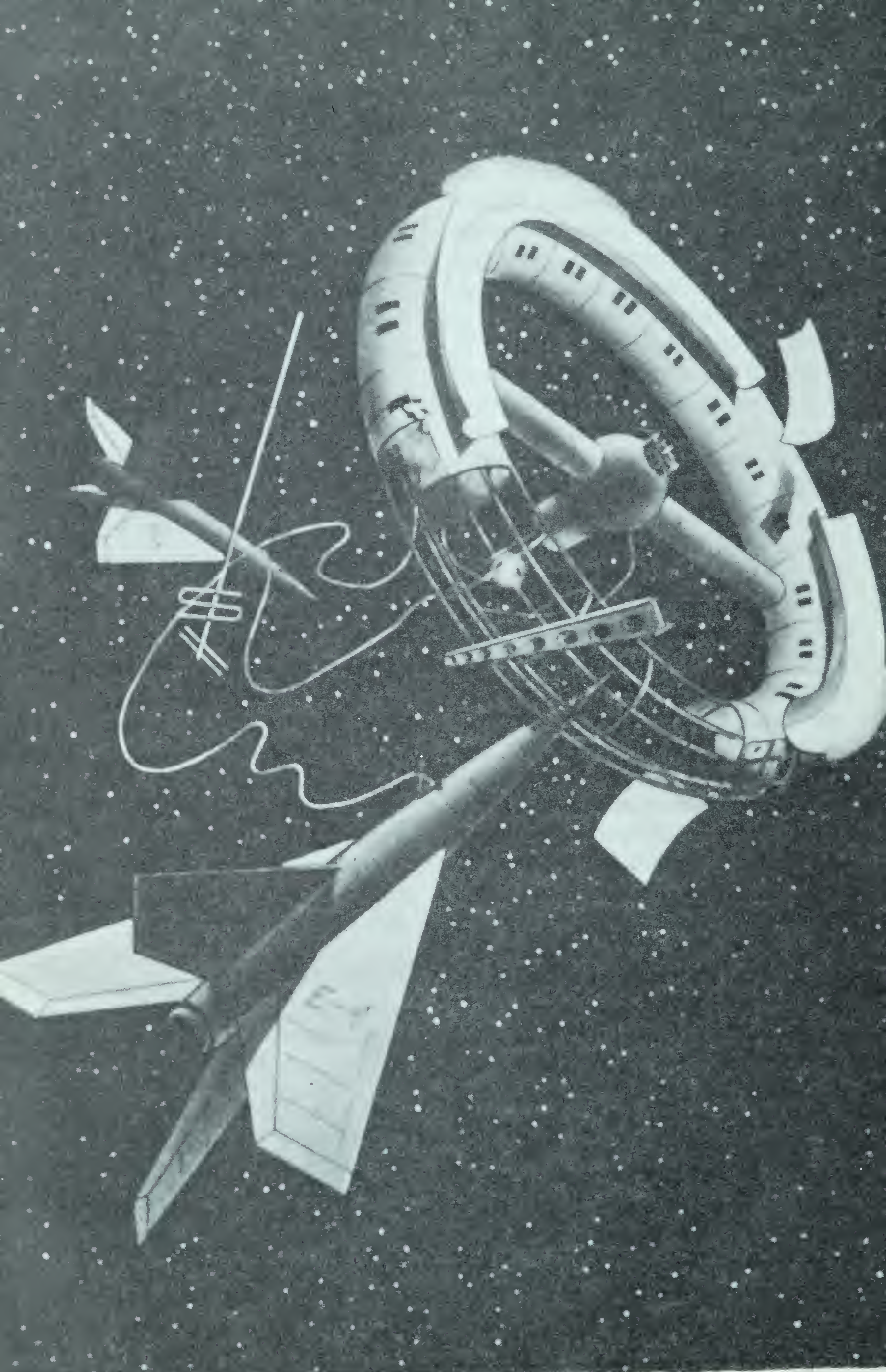
The manned satellite will determine how human beings react in space. It will also allow man to test space suits, air-conditioning units, and other specialized equipment. After about 20 revolutions around the earth, small rockets will be used to slow down the ship so that it will fall safely back toward the earth. The ship would then glide down to a landing on earth just as the experimental rocket airplanes do today.

A permanent manned satellite might be the next step in space travel. Its parts would be carefully made on earth and ferried by rocket ships to the desired spot in space, where it would then be assembled. This would be easier than building it on earth and then launching it into space. In Fig. 8-11 we see an artist's drawing of the "space station" under construction. Such a space satellite would be valuable for obtaining further knowledge of space. It would serve as a training base for space men. It is even possible that the space station might be used as a construction base for other types of space craft to carry on further exploration of the solar system.

Unknown factors may make it necessary to revise or abandon present plans for space travel. However, our knowledge to date indicates that the idea may possibly be practical. Scientists and engineers must still work out all the details, which are considerable. However, once the preliminary facts were known about the uses for atomic energy, scientists made rapid progress in developing these uses. Perhaps the same will be true of space travel.

REVIEW QUESTIONS

1. Why will space ships and space suits be pressurized? **2.** What speed is necessary to escape from the earth's gravity? To maintain an orbit around the earth? **3.** What do scientists mean when they use the term *g?* **4.** What radiations are more dangerous in space than on the earth's surface? **5.** What is a three-stage rocket? **6.** How could an unmanned rocket ship advance our knowledge of space?



C What are the star constellations?

The stars are beyond the solar system. Each star is a large, gaseous body, giving off its own light and heat just as the sun does. But the stars are trillions of miles farther from the earth than the sun is. Hence they cannot warm or light the earth the way the sun does.

A *constellation* is a group of stars forming a pattern or figure. In early times there was no artificial light, such as candles or lamps. The stars were the only objects visible at night except, of course, the moon. Men noticed that many groups of stars, or constellations, were apparent in the sky. The stars seemed to move but always kept their relative positions. They thought the sun moved around the earth and caused day and night.

Now we know that the earth moves, and the stars only seem to move. The only star that seems to be in the same position at all times is the pole star, or *North Star,* sometimes called *Polaris.* If you were standing at the north pole of the earth, Polaris would be almost directly above you.

The best known constellation and the one you can most easily see is the *Big Dipper,* also called the *Big Bear.* The two stars at the side of the Big Dipper opposite the handle are called the *Pointers.* This is because the line connecting them points almost straight toward the North Star, no matter what the position of the Dipper.

The stars are many light years away from the earth. Light travels about 186,000 miles a second. It takes light only eight minutes to travel from the sun to the earth. Ordinary measurements like feet or miles are of little value in estimating the great distances to the stars. In astronomy a *light year* is the distance light travels in one year, or if expressed in round figures, six trillion miles.

The star, *Alpha Centauri,* which can be seen from the southern parts of

Fig. 8-12. The stars near the North Pole circle about it once every 24 hours. By taking a time exposure, you can get the bright, curved star trails which appear in this picture.

← **Fig. 8-11.** An artist's painting of a possible space satellite. (Adapted from *Worlds in Space* by Martin Caidin.)

the United States, is 4.3 light years away. *Sirius* is the brightest star in the sky, and is nine light years away. *Arcturus* is 36 light years away. *Betelgeuse,* the giant star, is 296 light years away. It is so large that the sun, with the earth revolving around it, could be placed inside it.

Stars are grouped by magnitudes. Some stars are much brighter than others. Ancient astronomers therefore grouped them into *classes* or *magnitudes*. The *magnitude* of a star is the brightness of that star according to a set scale. Thus astronomers could distinguish the different groups of stars according to brilliancy.

There are only six magnitudes which we can see without a telescope. The stars in one magnitude are two and one-half times as brilliant as those in the next magnitude.

The 20 brightest stars belong in the first magnitude. There are 65 second magnitude stars, including those making up the Big Dipper and the North Star itself. The third magnitude includes 190 stars.

There are about 5,000 visible stars in the first six magnitudes. But you can only see about half at any one time.

PUPIL ACTIVITY

Look in the northern sky for the Big Dipper and locate the North Star and the Little Dipper as shown in Fig. 8-13. Later the same night look again for these constellations. Are they in the same positions as earlier? Draw a rough diagram to show any changes you observe.

The constellations may be identified by use of star maps. Once you have found the Big Dipper and North Star it should be easy to locate some of the other constellations. Using the star maps in Fig. 8-15 and Fig. 8-16, try to find those shown.

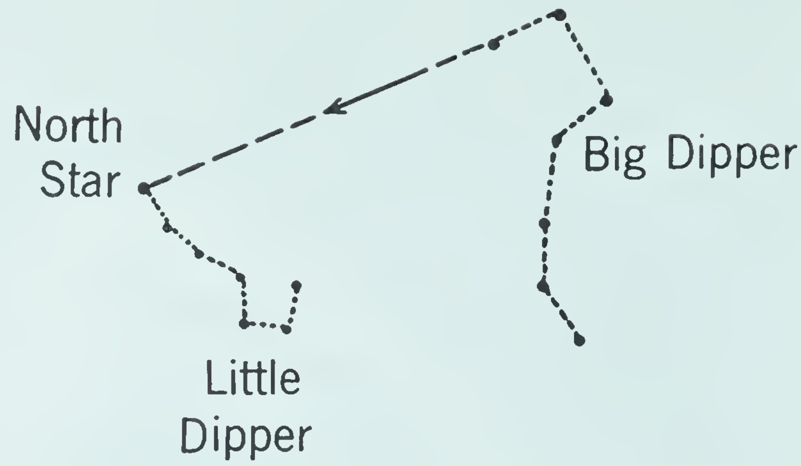


Fig. 8-13. The location of the Big Dipper makes it possible to locate many other constellations.

PUPIL ACTIVITY

Draw a rough star map similar to Fig. 8-15 to show a few of the constellations as seen at 7 P.M. Find the same constellations at 9 P.M. and draw them in their new positions.

From these observations it should be clear that, although the constella-

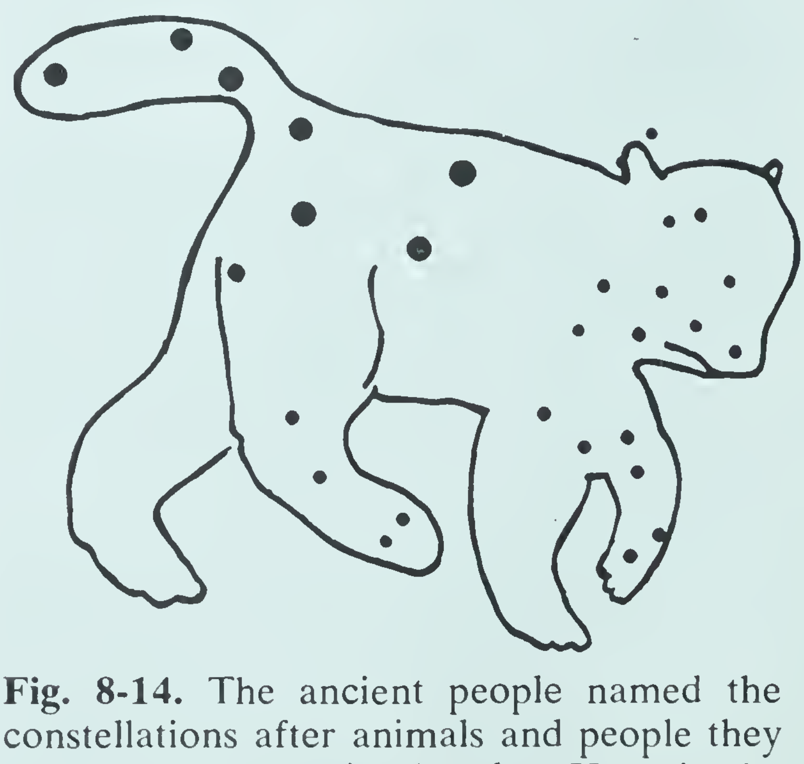


Fig. 8-14. The ancient people named the constellations after animals and people they thought they saw in the sky. Here is the constellation of the Big Bear as they imagined it. Can you find the Big Dipper?

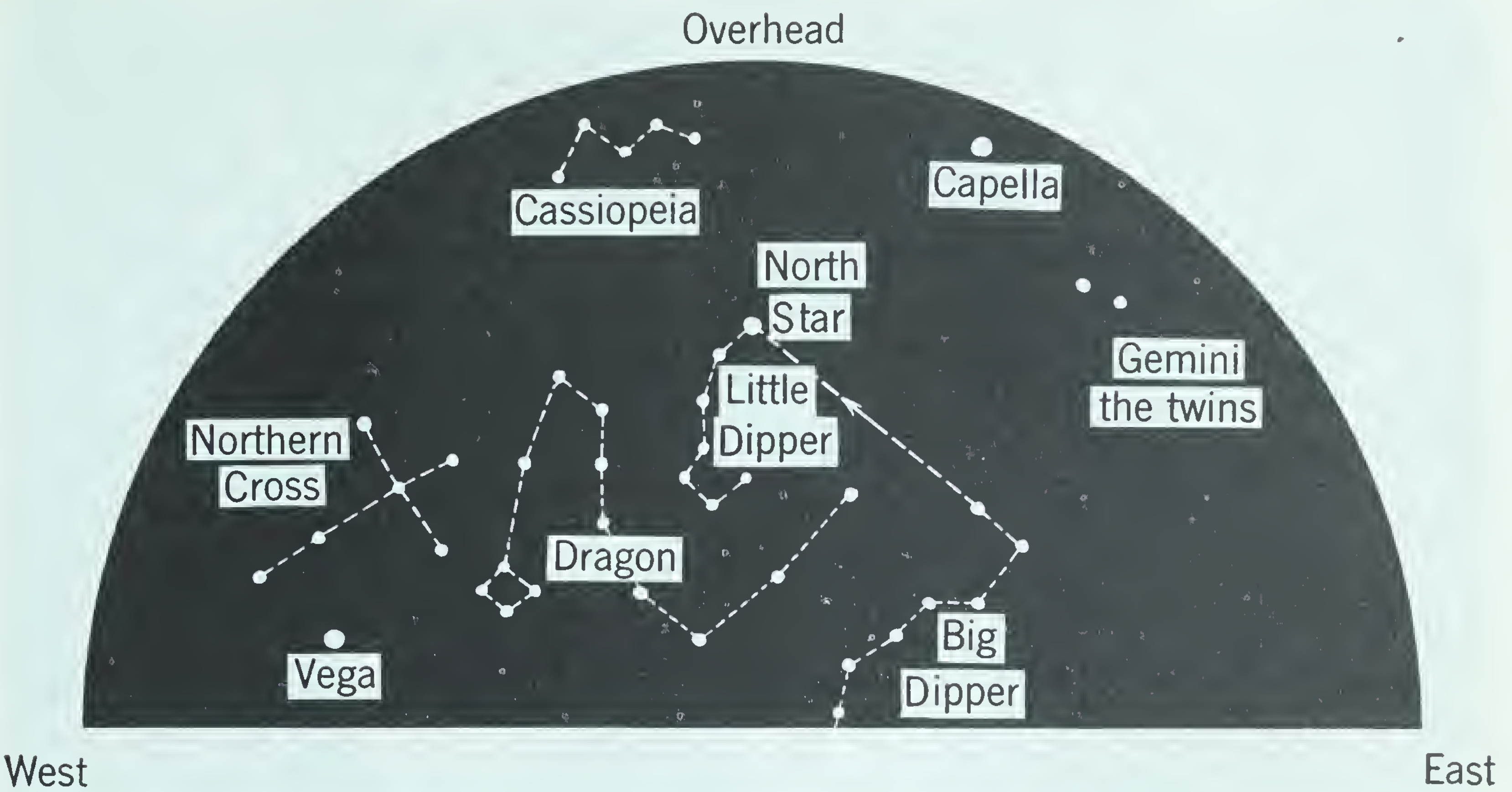


Fig. 8-15. This star map shows the constellations in the northern sky about 8 P.M. in January.

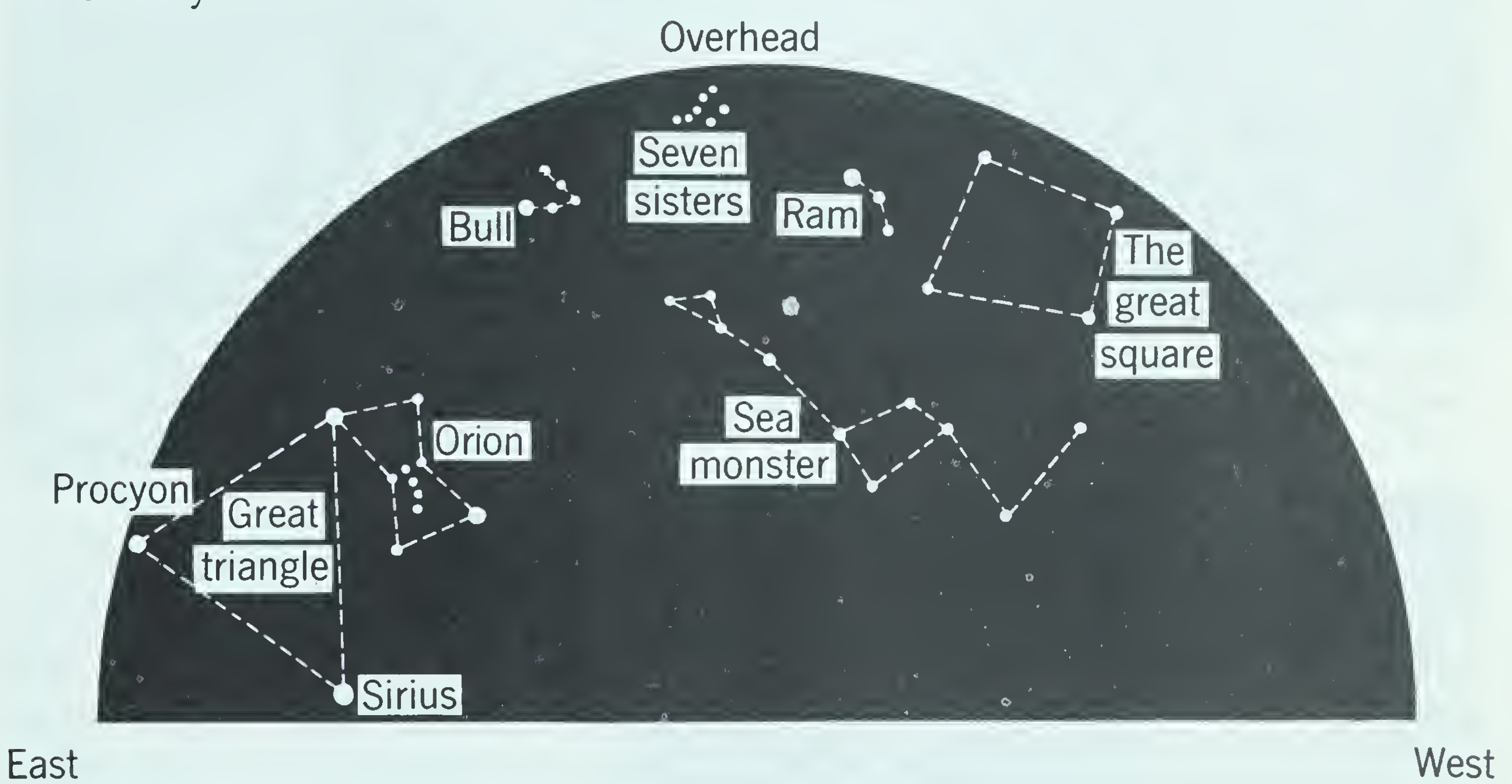


Fig. 8-16. Facing south, you might see these constellations about 8 P.M. in January.

tions keep the same position with respect to each other, they seem to move through the sky as the night passes.

If you look at star maps in astronomy books, you may find constellations not shown in Fig. 8-15 and Fig. 8-16. Can you explain why you cannot see all the constellations on any one night?

PUPIL ACTIVITY

To test your ability to identify the constellations, draw two star maps, one facing east and the other west. Include the constellations identified in previous observations. Compare your star maps with Fig. 8-15 and Fig. 8-16. How are they similar? What differences are there? Explain the similarities and differences.

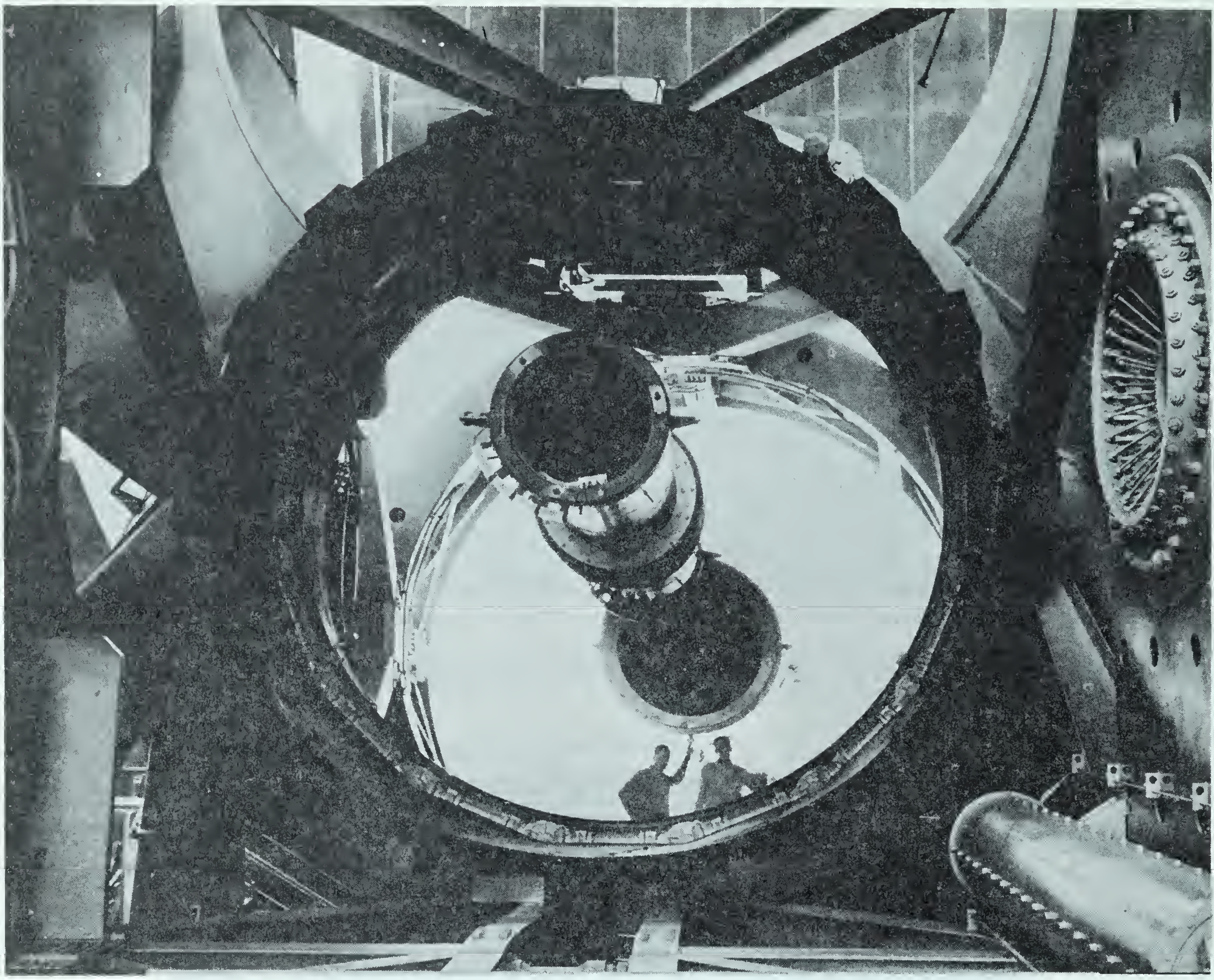


Fig. 8-17. The vast mirror which reflects two scientists at the Mount Palomar Observatory was twenty years in the making. The giant telescope can photograph stars a billion light years away from the earth.

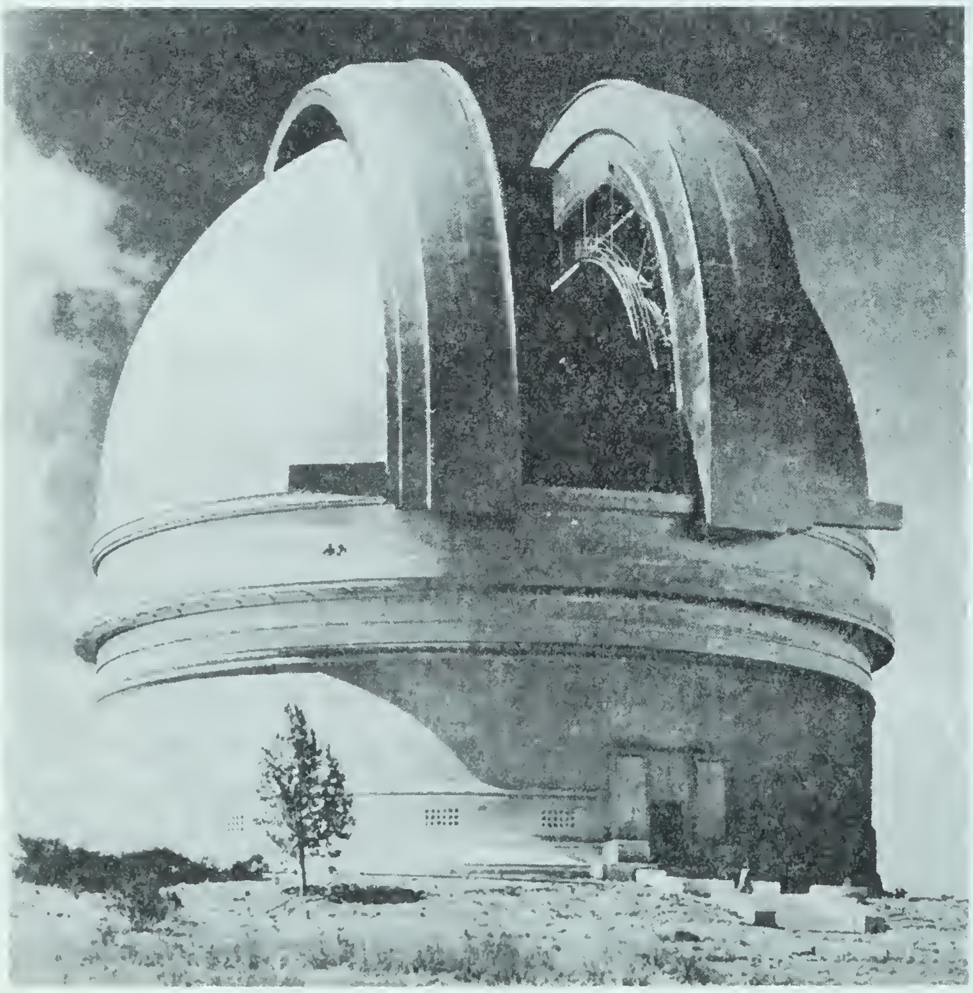


Fig. 8-18. The dome of the Palomar Observatory in California contains the world's largest telescope.

The Milky Way contains billions of stars. On a clear, moonless night you can see a group of stars across the sky. For part of the way two groups appear to run parallel to each other. These two groups form the *Milky Way*. It has so many stars that the light from them appears to form one continuous band.

REVIEW QUESTIONS

1. What is a constellation? A star? **2.** At the same time of the night why does the Big Dipper appear in a different position during each month of the year? **3.** What are the first magnitude stars? **4.** How much brighter are first magnitude stars than those of second magnitude? **5.** What is a light year? **6.** What is the Milky Way?

D What causes night and day and seasons?

The rotation of the earth on its axis causes night and day. The earth rotates on its axis in a west to east direction once every 24 hours. One side is turned toward the sun and therefore receives sunlight; it is day. The other side is turned away from the sun and gets no light; it is night. The side tilted toward the sun has longer days and shorter nights than the side tilted away from the sun.

The earth's axis from pole to pole is tilted approximately 23½° away from the perpendicular to the plane of the earth's orbit around the sun. If it did not tilt, night and day would always be equal in length, or 12 hours each.

DEMONSTRATION

Use a flashlight that projects parallel rays of light, or any lantern that sends out light in parallel rays. Darken the room. Rotate a small globe, holding its axis in a vertical line, in the rays of light. Which part of the globe is lighted? Not lighted? Next, tilt the axis about 23.5 degrees to a vertical line through the center of the globe. Rotate the globe. How do the parts receiving light change as the globe is tilted?

In winter, the northern hemisphere is tilted away from the sun slightly. Therefore, its days are shorter and its nights are longer. In summer, the rays of light from the sun shine on all the North Pole area. The result is that the sun may shine there 24 hours a day for several days. The seasons in the southern hemisphere are the reverse of ours. When it is winter in Canada it is summer in Australia.

The tilting of the earth's axis as described above causes the seasons. The earth revolves around the sun in a counterclockwise direction once a year. As the earth revolves, always with its axis tilted, the sun's position in respect to the earth's equator seems to move.

Examine carefully Fig. 8-19 and notice that the sun is directly above the southern hemisphere in winter. As the earth continues to revolve, the sun seems to move slowly northward. However, it is the combination of the earth's revolution and its tilt which makes the sun appear to do so.

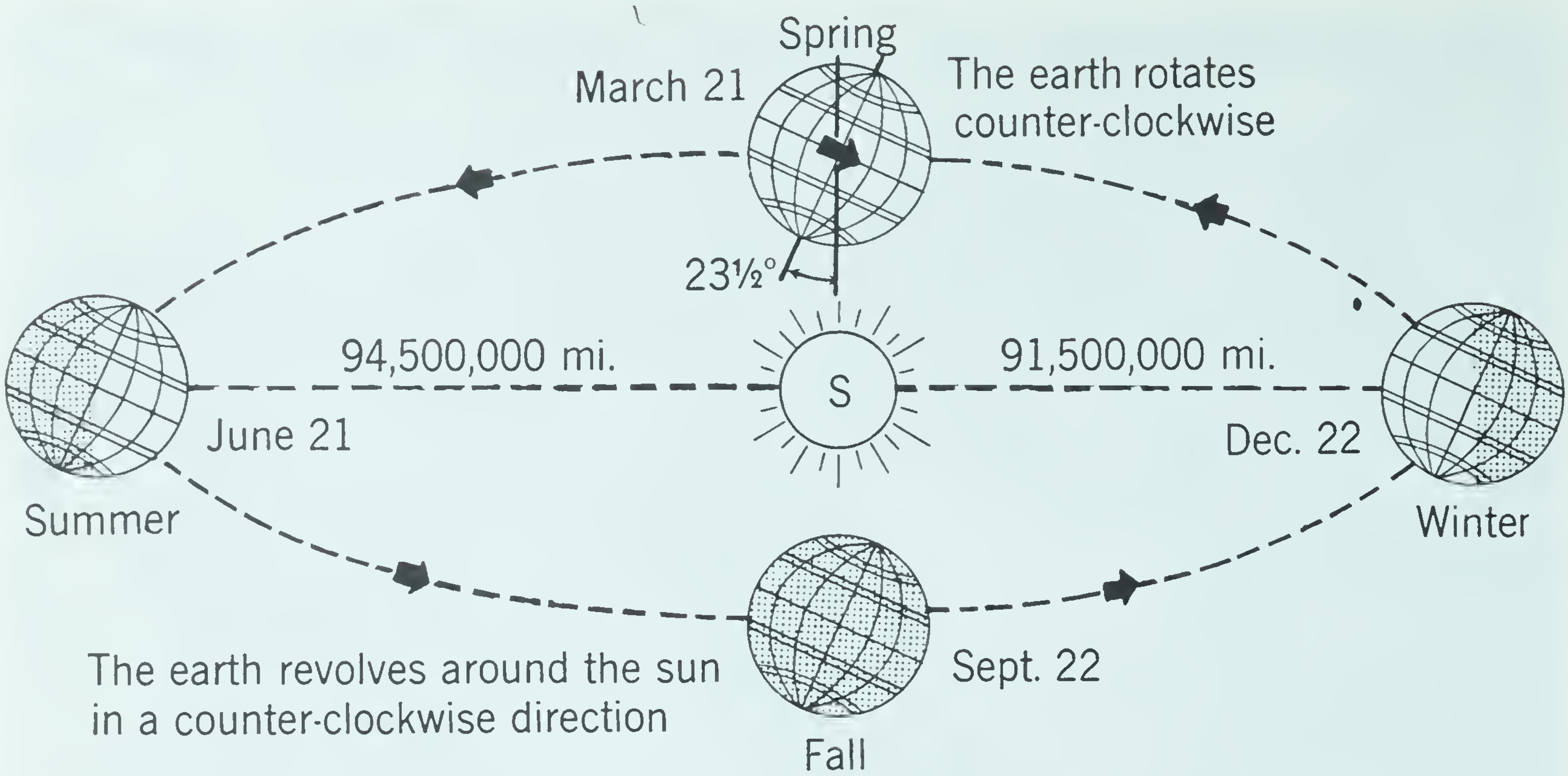


Fig. 8-19. The earth rotates on its axis once every 24 hours, causing night and day. The tilting of the earth's axis causes the change of seasons.

The longest day of the year is June 21 and the shortest day is December 22. Days and nights are of equal length on March 21 and on September 22. The northern hemisphere has summer in July because then the days are long. Also the rays of the sun strike the earth almost perpendicularly. This gives the northern hemisphere more heat. Also, with short nights the northern hemisphere has less time to cool.

The sun is three million miles nearer the earth in winter than in summer. However, nearness of the sun to the earth is not the most important factor in heating the earth. In addition, the angle at which the sun's rays strike the earth is also important.

DEMONSTRATION

Direct parallel rays of light from a flashlight or lantern against a globe so the rays are perpendicular to the globe at its equator, as shown in Fig. 8-20. Then gradually move the horizontal rays toward the poles of the globe. Also tilt the globe so the horizontal rays can strike it at many different angles. In what position do the rays cover the smallest area on the globe? The largest area?

You can repeat the demonstration by using a paper or metal tube open at both ends. Let the rays from the sun pass through the tube and strike a cardboard held perpendicular to the tube. Then tilt the cardboard so the rays of light strike at different angles. Compare the area covered by the rays when striking the cardboard at different angles.

When the sun's rays strike the earth perpendicularly, the area covered by a certain quantity of light is less than at any other angle. This means that more rays are absorbed over a smaller area. When the rays strike at any other angle, the area covered is greater and the quantity absorbed per unit area is less. The rays must also pass through more air when

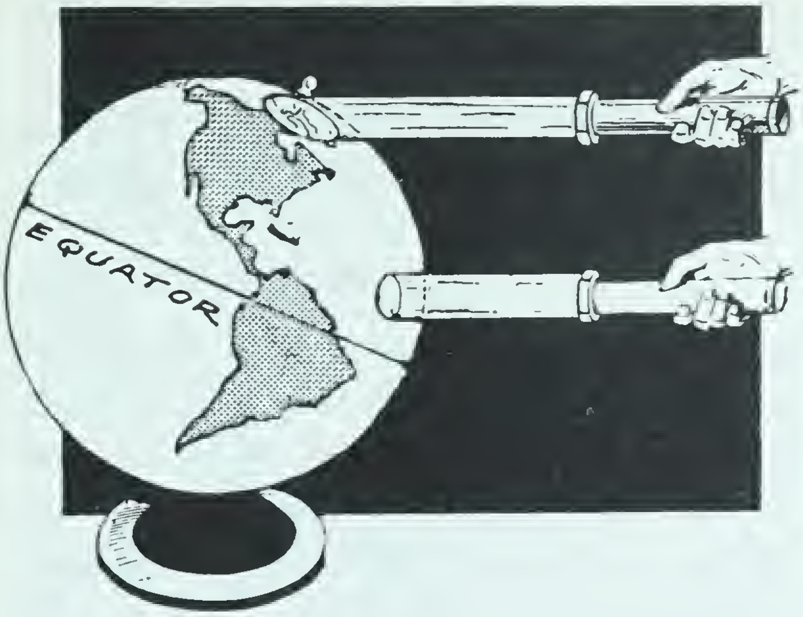


Fig. 8-20. As you can see in this demonstration, parallel rays cover a smaller area when they strike the earth perpendicularly.

striking at any other angle. More heat is absorbed by the air and the quantity of heat reaching the earth is less. In summer, the temperature is higher because the sun shines longer. The same number of rays strike a smaller area. The result is that the heat is more intense, and less is absorbed by the air.

The air around the earth is heated mostly by radiation from the earth. The air absorbs very little heat from the direct rays of the sun. The sun's heat energy is absorbed by the earth and objects on it. When the earth is warmed, it radiates heat to the air above it. As the air is warmed, it is pushed up by the colder and heavier air. Thus a circulation is set up and all the air is heated gradually. The warmer the earth, the more rapidly the air is heated.

REVIEW QUESTIONS

1. How long does it take the earth to rotate on its axis? To revolve around the sun? **2.** What is a day? A year? **3.** What causes the seasons? **4.** Give three reasons why North America is warmer in summer than in winter. **5.** In what direction does the earth rotate on its axis? Revolve around the sun? **6.** How is the earth's atmosphere heated?

Fig. 8-21. Here you see the midnight sun in Norway. Explain why the sun never seems to set in summer in the far northern latitudes.

E How can you tell direction by day or night?

You can tell direction on a sunny day by using your watch. If a ship were in trouble on the ocean, it would be useless to send a message saying that it was lost. One would have to know its exact position in order to rescue it. How do aviators find their way across the Atlantic and Pacific, and over large areas of land?

Have you ever thought how difficult it would be for travelers to go long distances over land and water if they did not have scientific instruments to guide them on their way? You can determine direction roughly by using your watch.

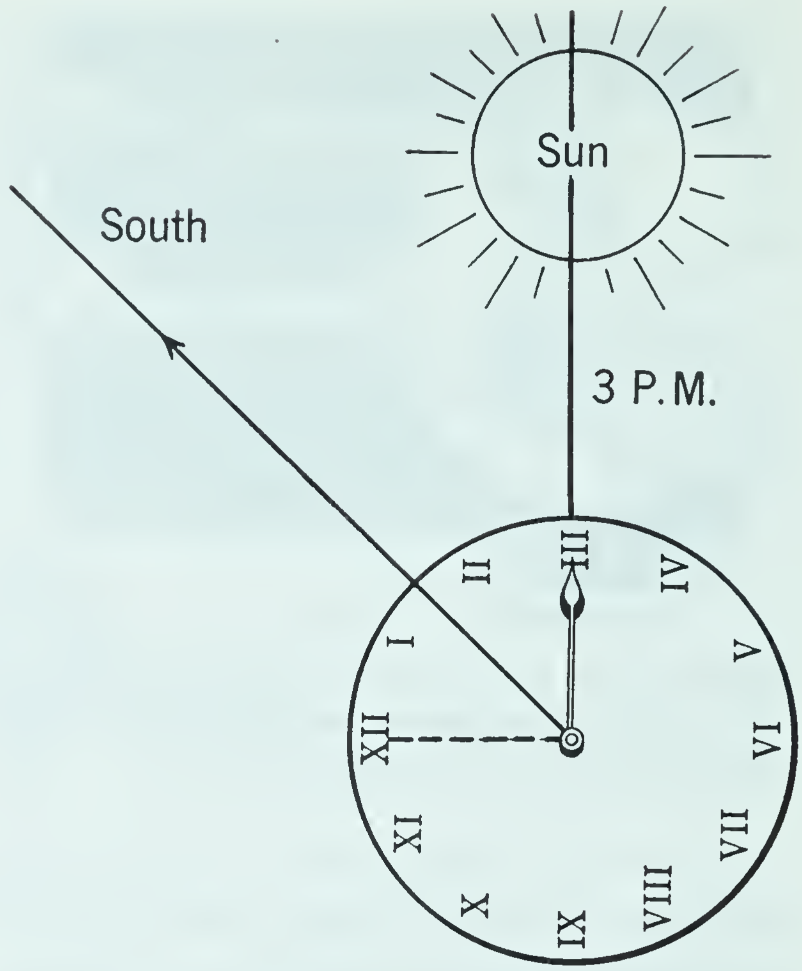


Fig. 8-22. How can you tell direction on a sunny day by using your watch?

PUPIL ACTIVITY

Hold a watch face upward in the palm of your hand. Hold a straight twig or match stick upright at the end of the hour hand on the circumference of the dial. Now rotate the watch so that the shadow of the stick falls directly on the hour hand of the watch (see Fig. 8-22). The point on the dial that lies halfway between the tip of the hour hand and the figure 12 will indicate approximately the direction south.

Repeat this several times at different hours of the day. Do you get the same direction for south in each trial? Can you explain why this experiment gives the southerly direction? Check the directions obtained with a watch with those obtained with a compass. Which is more accurate?

The watch may help you get direction when you have no other instrument with you. But it can be used only when the sun shines.

You can use a compass to find direction by day or night. The earth itself is a great magnet with north and south magnetic poles. You can mag-

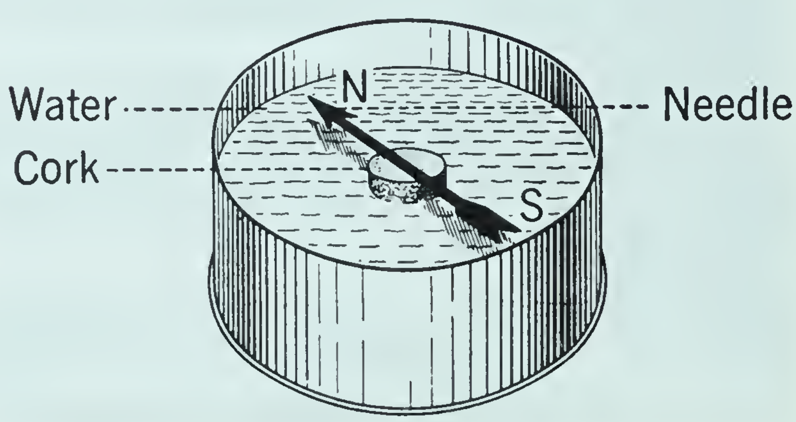


Fig. 8-23. A floating compass will point in a north and south direction.

netize a piece of steel and then suspend it away from magnetic objects. It will point in a direction determined by the magnetic force of the earth.

DEMONSTRATION

Magnetize a steel needle by stroking it from end to end with the N pole of a magnet, stroking always in the same direction. Thrust the magnetized needle through a cork. Float the cork on water in a glass or porcelain dish so that the needle is parallel to the surface of the water. Does the needle tend to point in any direction? Try the same demonstration with an unmagnetized needle. Result?

The two ends of a magnetic needle are known as its *poles.* The pole that points northward when the magnet is freely suspended in the middle is the *north pole* of the magnetized needle. The end pointing southward is the *south pole.* The earth's northerly magnetic pole is in the region northwest of Hudson's Bay, while the southerly magnetic pole is about 1,400 miles from the south geographic pole on the Antarctic continent.

Even in Columbus' time it was known that the needle does not point true north and south everywhere. Study the map in Fig. 8-24 showing the variations of the compass needle from true north and south direction.

Evidently a traveler can depend on the compass to give him true north in only a few places. We call the variations of the needle from true north and south the ***declination*** (deck-lin-*ay*-shun) of the needle. Refer again to

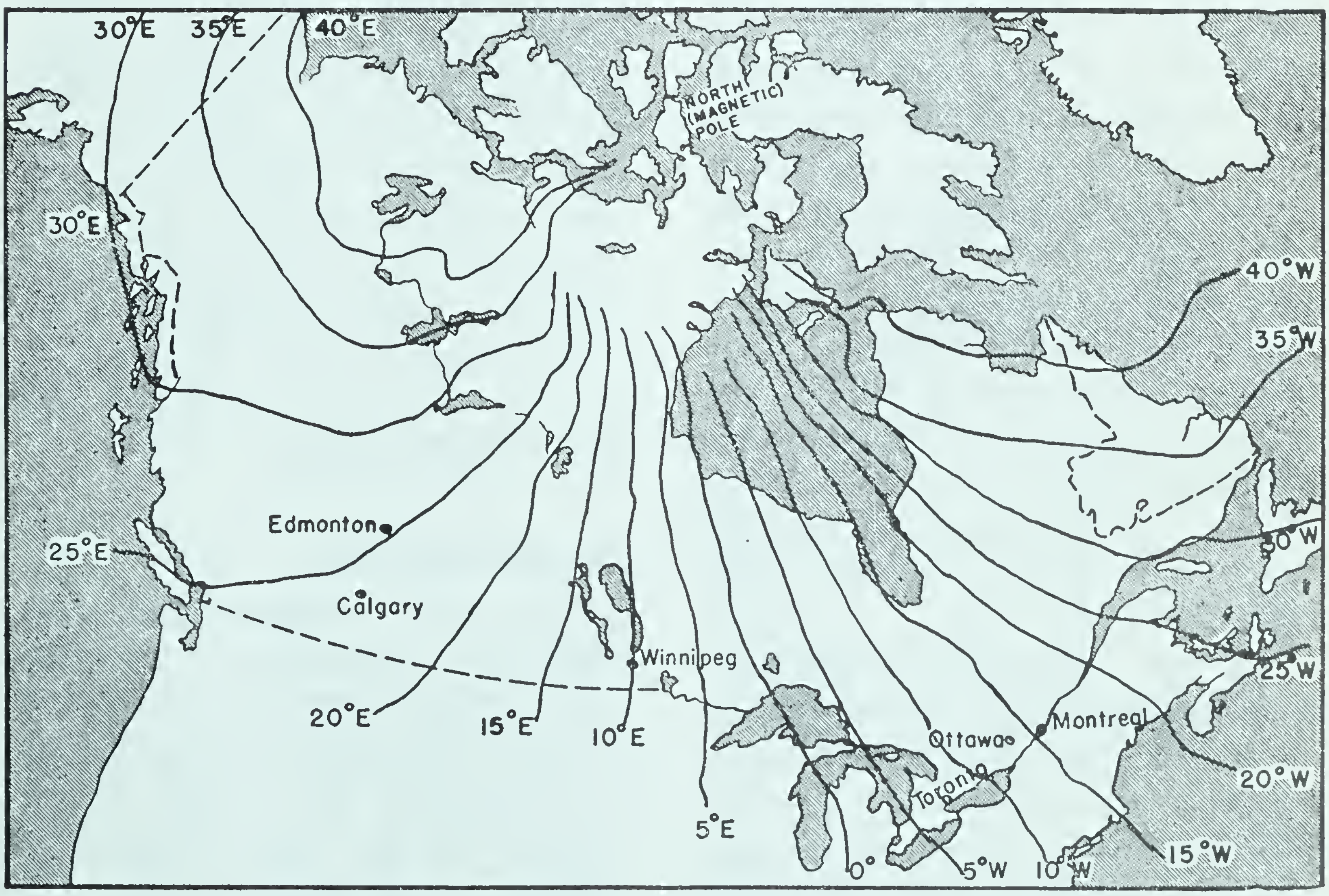


Fig. 8-24. This map shows the number of degrees a compass needle is deflected from true north in various parts of Canada.

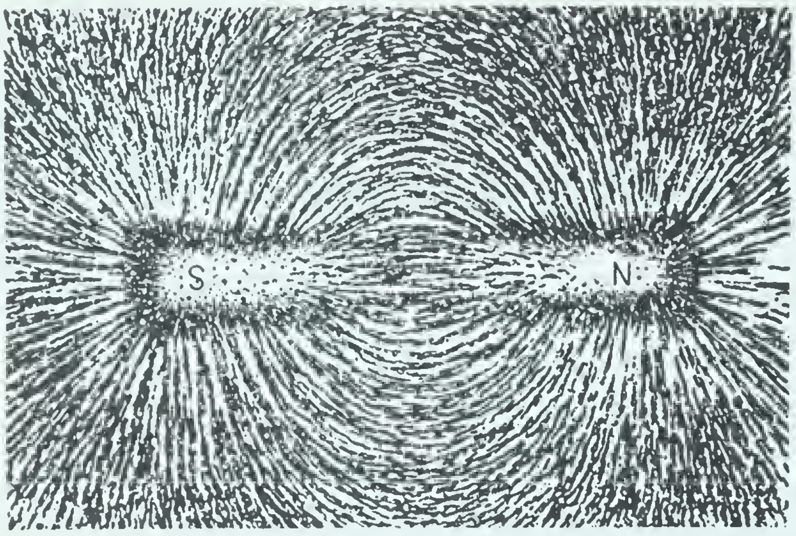


Fig. 8-25. A piece of magnetized steel shows properties similar to the earth's magnetic properties.

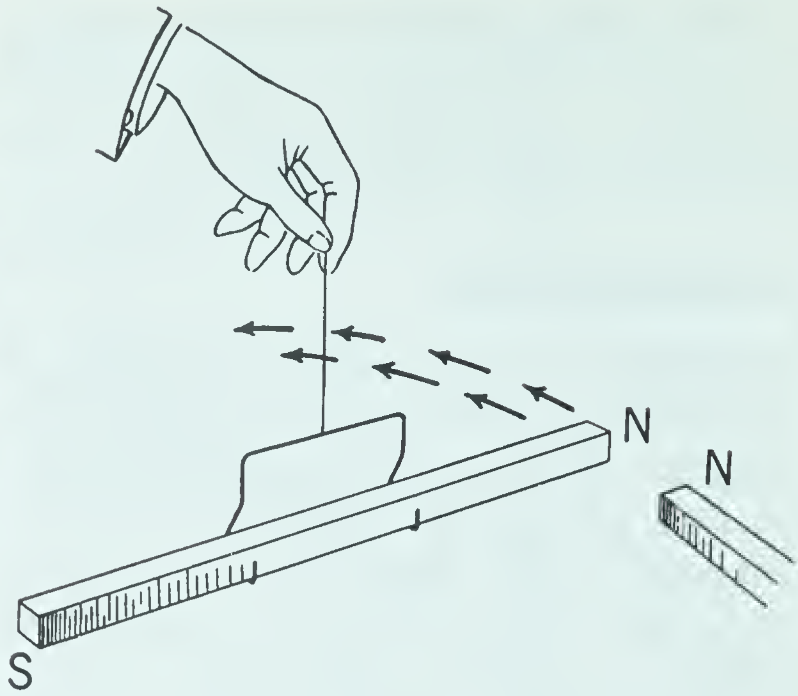


Fig. 8-26. By bringing another magnet near a suspended magnet, you can move the suspended one.

Fig. 8-24. In what direction would the compass point in Manitoba? In Alberta? In Newfoundland? Where is the line of no declination?

These lines of declination are on pilot charts used by sailors and aviators. Thus at any given point, they know just how far from true north the compass is pointing. They can then make the necessary allowances.

One type of compass is not magnetic. It uses the principle of the gyroscope. Recall that a gyroscope, once it is spinning, resists efforts to change the direction of its axis. For this reason, the axis of a gyroscope once pointed in a N-S line maintains its direction. A gyrocompass is not subject to error because of declination. Explain why this is so.

You can determine direction from the sun during the day. If you face the sun at noon, your right arm extended will point west and your left arm will point east; north will be behind you. This is a simple method of getting your general direction as you travel. But the direction you get in this way is only approximately correct and can be found only in sunshine.

It is not always wise to depend on a single method of telling in what direction you are traveling. If you use a compass it may be affected by various factors, such as some metals. You can always use the North Star or other stars on a clear night, and the sun on a clear day. You can easily locate the North Star which is nearly true north. It is prominent in the sky and lies in the line of the two stars at the bowl end of the Big Dipper.

REVIEW QUESTIONS

1. Why does a compass needle point nearly north and south? **2.** How are the earth's magnetic poles located? **3.** How has the compass helped exploration? **4.** How can you get direction from the sun? From the stars? **5.** At what points in Canada does the compass needle point straight up and down? **6.** Why is a gyro-compass more reliable than a magnetic compass?

F How are different positions on the Earth's surface located?

Instruments measure latitude and longitude. Any place on the earth's surface is determined by measuring degrees of latitude and longitude. You recall that a circle is divided into 360 equal parts called *degrees*. Degrees are divided into 60 equal parts called *minutes*. Minutes are divided into 60 equal parts called *seconds*.

If we regard the circumference of the earth as a circle, then the distance from the North Pole to the South Pole is 180°. Thus you can express any distance from the equator toward a pole in degrees. This is called ***latitude***. The equator is 0° latitude. The North Pole is 90° north latitude. The South Pole is 90° south latitude. A point half-way between the equator and the North Pole would be at 45° north latitude.

If we select any line from North to South Poles, called a ***meridian*** (see Fig. 8-27) as the starting point, the distance from it east or west can be represented in degrees. This is called ***longitude*** (*lon*-jih-tude). Scientists have agreed to call that meridian running through Greenwich, England, the ***prime meridian*** with a longitude of 0°. Longitude 180° east and west of this meridian coincide on the opposite side of the earth. The International Date Line is placed, by agreement also, approximately along this meridian. Travelers crossing this line lose or gain a day in adjusting to standard time.

To determine a location, you must find north or south position in degrees, minutes, and seconds of latitude with respect to the equator. You must also find east or west position in degrees, minutes, and seconds of longitude. The observer is at the point where the circles so indicated intersect or cross. By referring to a prepared chart, the traveler can mark his exact position on the earth's surface. By making such notations, he can plot his course from day to day.

Sailors depend on this system of determining location, and their methods belong to the science of navigation. This science involves astronomy, accurate time keeping, and correct use of compass and other instruments.

Fig. 8-27. Longitude is measured in degrees east or west of the meridian which passes through Greenwich, England. Latitude is measured in degrees north and south of the equator.

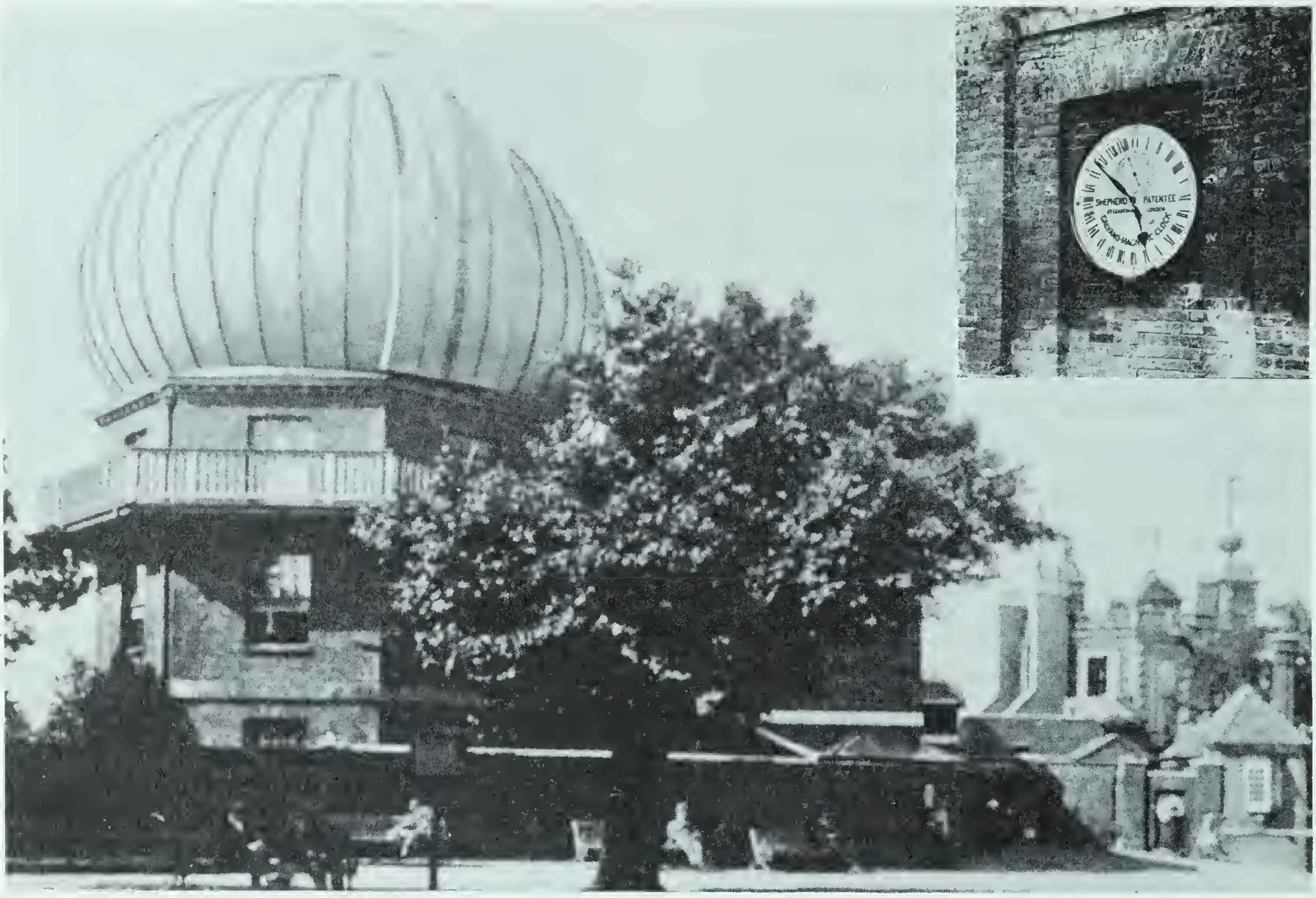


Fig. 8-28. The first buildings for the Royal Observatory in Greenwich, England, were designed by Sir Christopher Wren. This is how they looked prior to 1946 when it became necessary to move the observatory. The clock on the wall by the gates (seen also in the insert) gave the official Standard time for the whole world.

Latitude is found by astronomical observations. Latitude can be determined in two ways. One is to measure the angle between the horizon and the North Star. At the North Pole the North Star would be exactly overhead, or at an angle of 90° with respect to the horizon. At the equator it would be on the horizon or 0°. The other way depends on measurement of the angle of elevation of the sun above the horizon at noon. For this you must have a navigation book to give you detailed information of the sun's elevation on that date. You can make rough determinations of the angular height of the sun or the North Star by a simple apparatus called a *quadrant.*

PUPIL ACTIVITY

Make a quadrant of cardboard, as shown in Fig. 8-29. Use a ruler for a sight line to mark the elevation of the sun or star on the quadrant. CAUTION: If you sight the sun, use a piece of smoked glass between your eye and the sun. Otherwise you may injure your eye.

Modern navigators use either a sextant or an octant to determine latitude. With the aid of these precise instruments for measuring angles, they can find the exact latitude of any place on earth. If they use the sun or any other star but the North Star for their measurements, they must take into account the date and exact time of their readings. Why?

Longitude is found by time comparisons. The earth moves through 360 degrees in 24 hours. Through how many degrees does it move in one hour? If the ship's time is two hours earlier than Greenwich time, then how far is the ship from Greenwich meridian? In what direction from this meridian is the ship? Greenwich time is kept on almost all ships by clocks called *chronometers* (kron-*nom*-ut-ters).

By exact observations and calculations, a sailor can determine the exact second by the chronometer that the sun crosses the meridian on which the ship is sailing.

From this calculation he finds noon for that location. Now suppose that the ship's time is noon, while the chronometer gives Greenwich time as 4 P.M. Since one hour's difference in time represents 15° of longitude or distance, evidently the ship in question is on the meridian that is 60° west of Greenwich. Explain why this is so. And why west?

The Dominion Observatory in Ottawa broadcasts the time every day. This makes possible an accurate time correction to be applied to the chronometer to make an accurate determination of longitude.

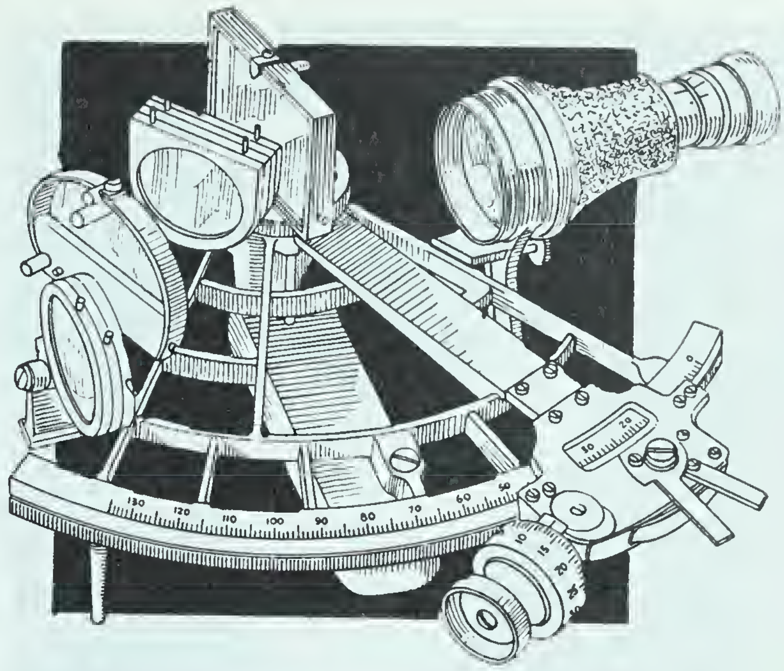


Fig. 8-30. With a sextant, a navigator can find the exact latitude of any place on earth.

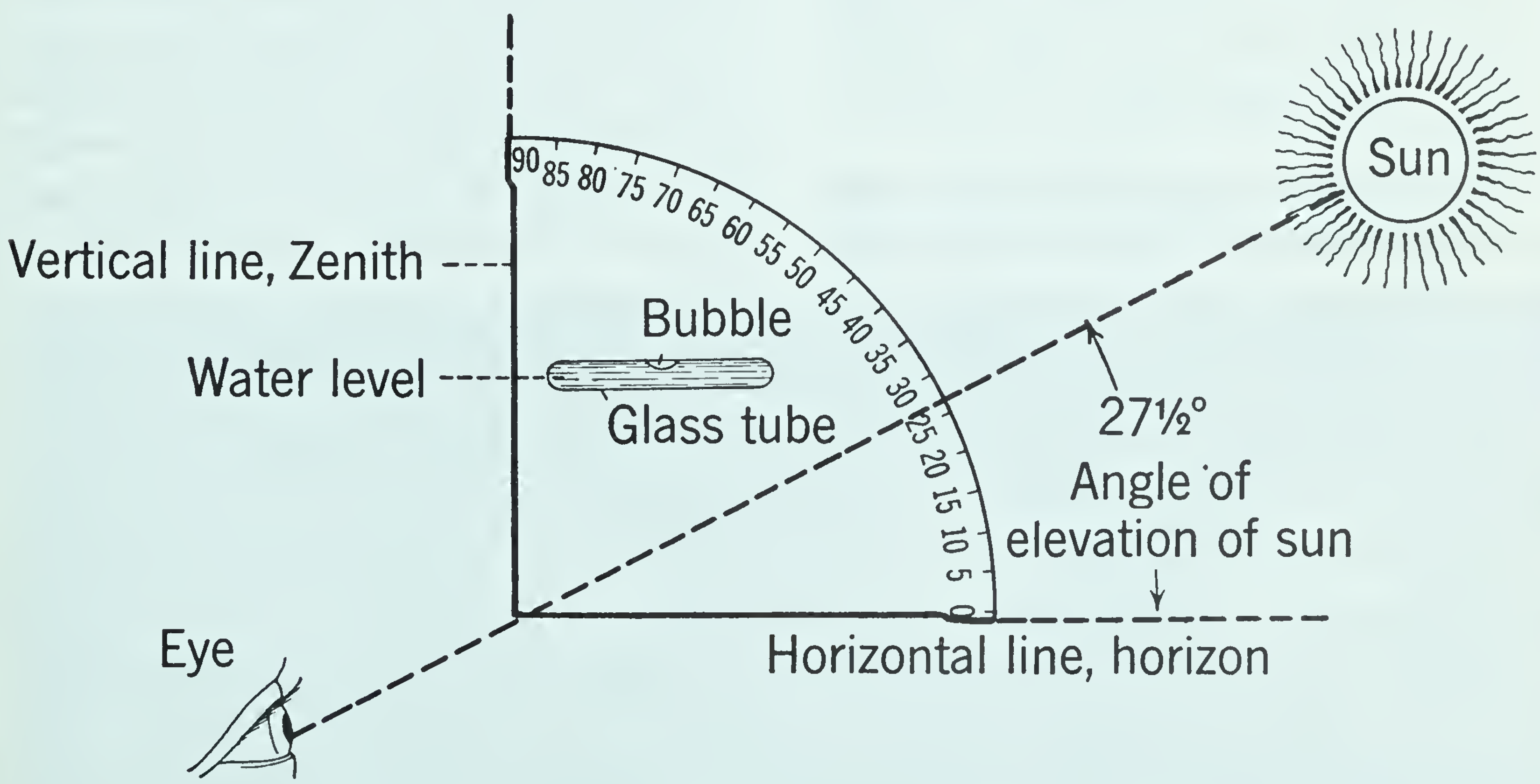


Fig. 8-29. With this homemade quadrant, you can find out the approximate angular height of the sun.

Fig. 8-31. This midshipman is using a sextant to "shoot" the sun.

You can now appreciate how navigators can fix their position so accurately. On long voyages by sea or air they are constantly checking their location by use of the sextant or octant and the chronometer. Thus they can travel thousands of miles and arrive at their destinations with little or no error.

The earth is divided into time belts for convenience. If sun time were kept everywhere, then two places near each other would not necessarily have the same time. The earth turns on its axis once every 24 hours. That is, it turns one twenty-fourth of 360°, or 15°, in one hour. For every 15° east or west of Greenwich, England, man uses a different time belt. (See Fig. 8-34.)

People in the same belt use the same time. The boundaries for these time belts do not always follow the lines of longitude. This is because it may be more convenient for some city to use time in an adjoining belt rather than the one in which it is located. Most of Ontario uses Eastern Time, although a large part of the province lies within the Central Belt.

Canada is divided into seven time belts: (1) Newfoundland, (2) Atlantic, (3) Eastern, (4) Central, (5) Mountain, (6) Pacific, and (7) Yukon. When you travel west and cross the boundary lines of one of these belts, you set your watch back an hour. If you travel east, you set your watch ahead one hour every time you cross a boundary. If you make a trip around the earth from east to west, starting at Greenwich, England, and set your watch back each time you cross the boundary of a time belt, by the time you reach Greenwich again you have lost an entire day!

To overcome this inconvenience, however, the International Date Line has been set in the Pacific Ocean in a position that will not cause difficulties if a day is lost or gained. If in going west, you reach this line at midnight on a Sunday, then the next day would be Tuesday. Or, if you are going east, then the next day after Sunday is Sunday, too! One day is lost, or one day is gained, depending in which direction you travel.

You can understand these facts if you start with the time in your locality and as your hand moves around a globe, set your watch back or ahead for every 15 degrees of longitude. What is the difference in time when you have returned to your original position? Most of the International Date Line is near 180° west longitude,

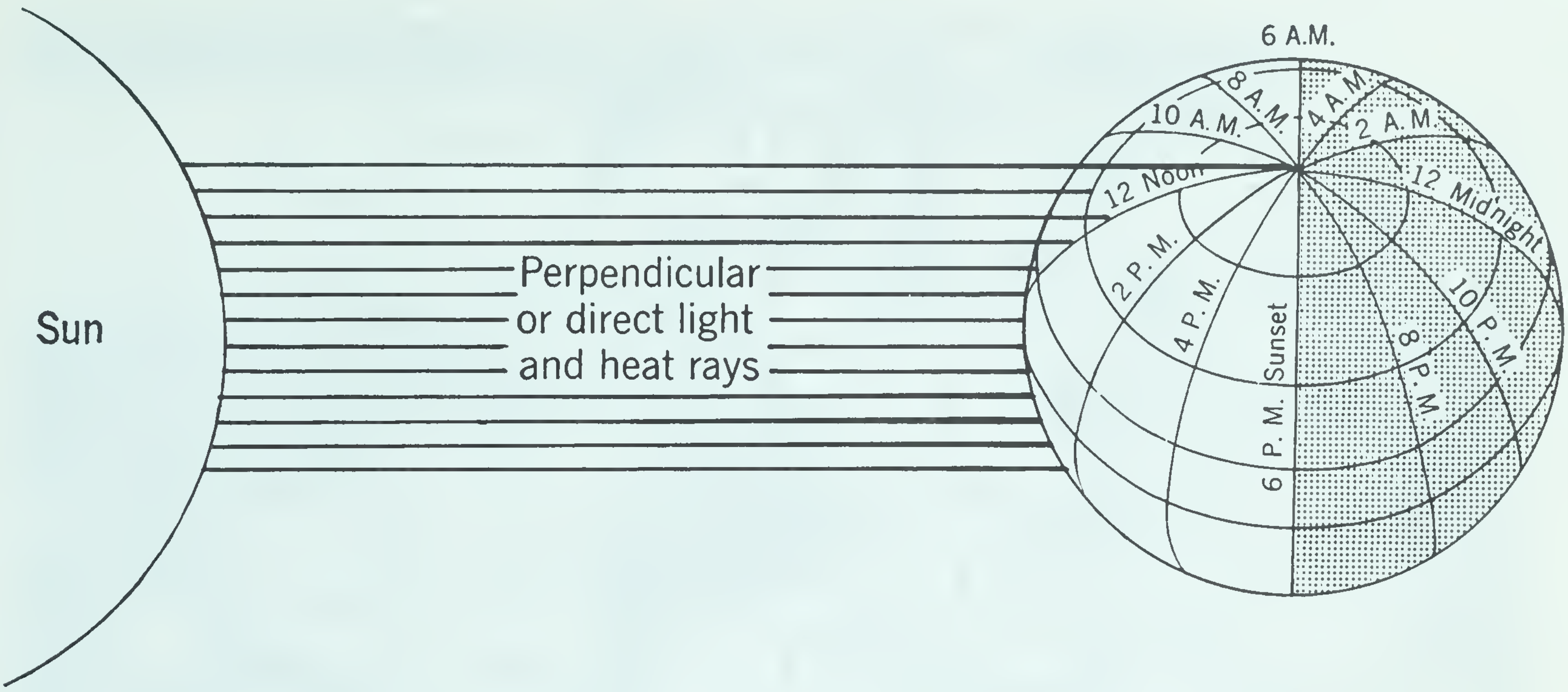


Fig. 8-32. Each time belt is about 15° wide, the amount which the earth turns on its axis in one hour.

or it could also be 180° east longitude. (See Fig. 8-35.)

Man uses the force of gravity to help him keep time. Galileo first discovered the possibilities of using a pendulum to keep time. A *pendulum* is any object that, when suspended from a given point, will swing freely back and forth. Once the pendulum is set in motion, it continues to swing for a long time. It will slow down and eventually stop due to friction and air resistance. It swings due to inertia of the pendulum and the pull of gravity.

One morning, Galileo observed the swinging of a chandelier. He noticed that the length of the arc had no effect on the time it took the chandelier to make one complete swing. He timed it with his pulse, for of course he had no watch, or any other method of accurately measuring time.

He then carried on further experiments and made a pendulum clock. Some of our present-day clocks are similar in principle to Galileo's first clock.

A few simple controlled experiments will help you to understand how you can use a pendulum to keep time.

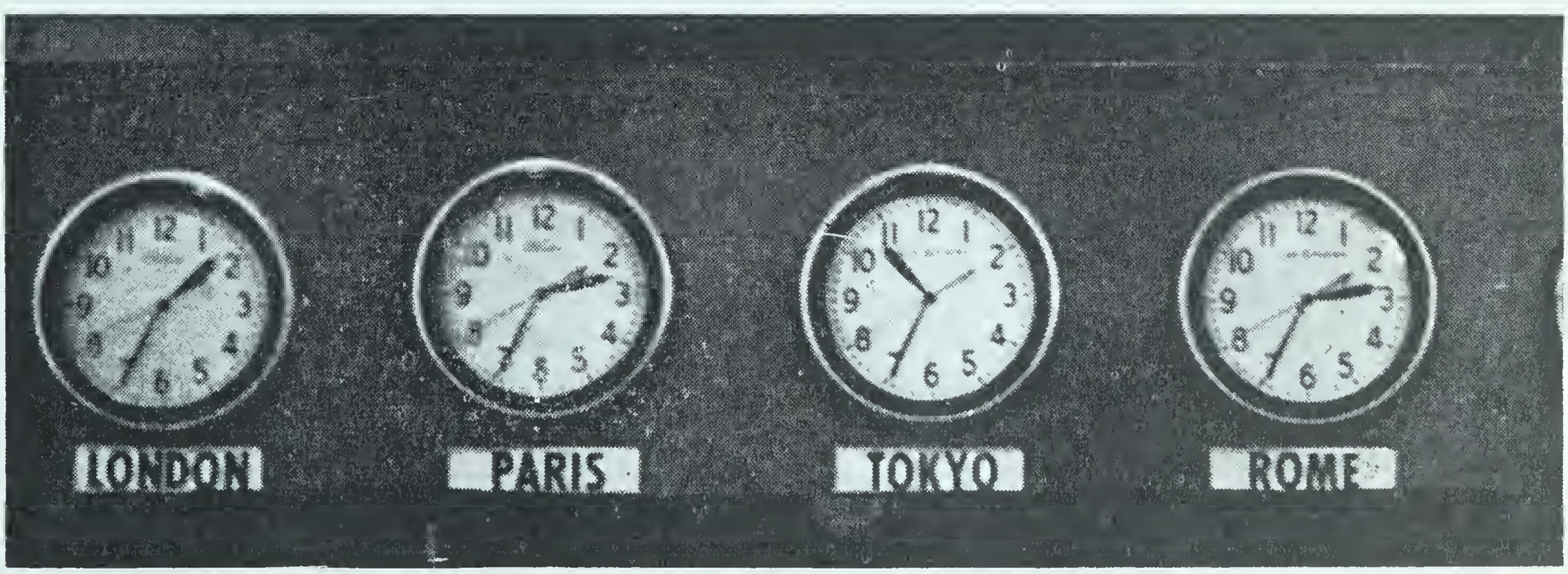


Fig. 8-33. Compare the difference in times in these four countries.

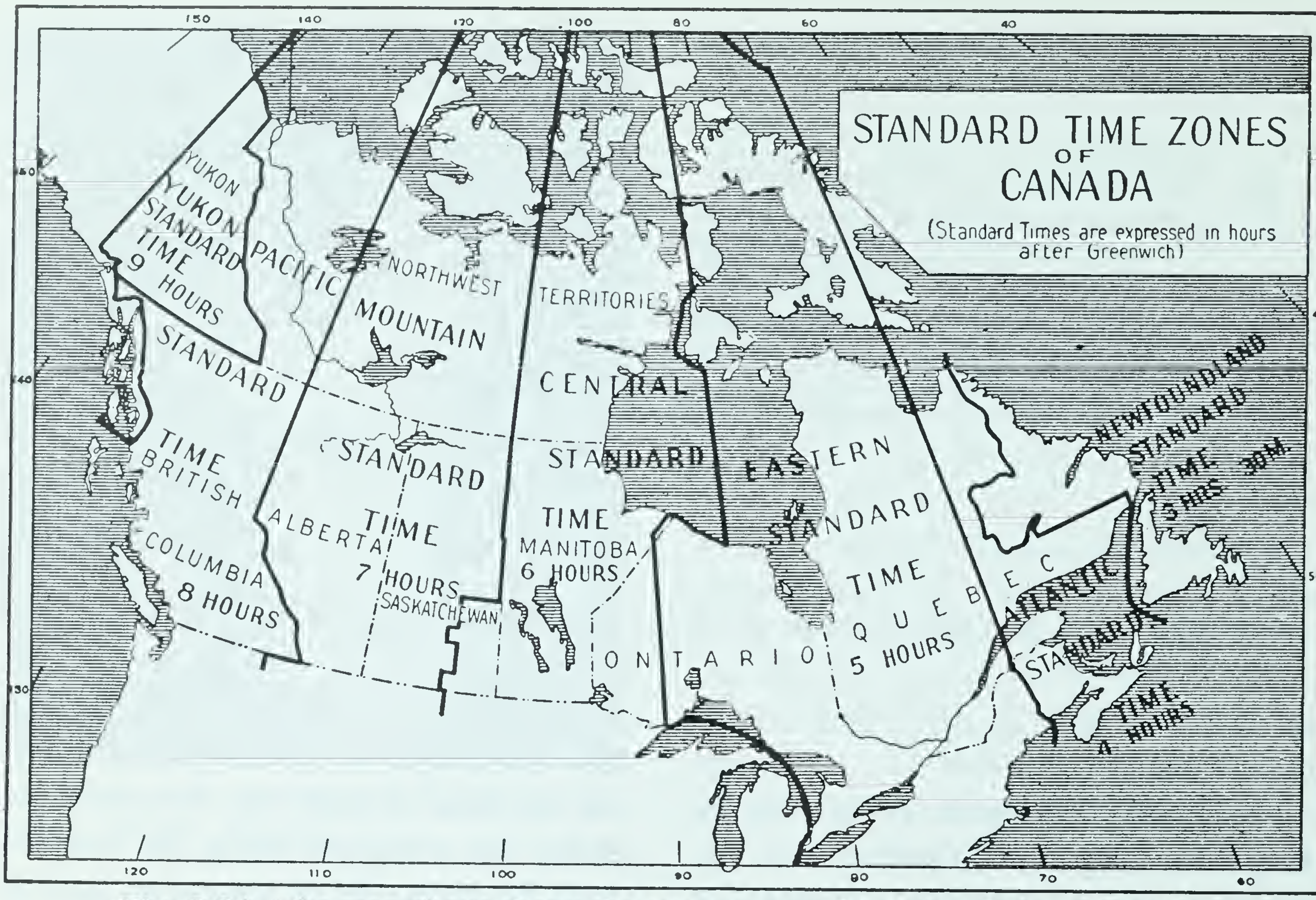


Fig. 8-34. The map above shows the seven geographical time belts of Canada.

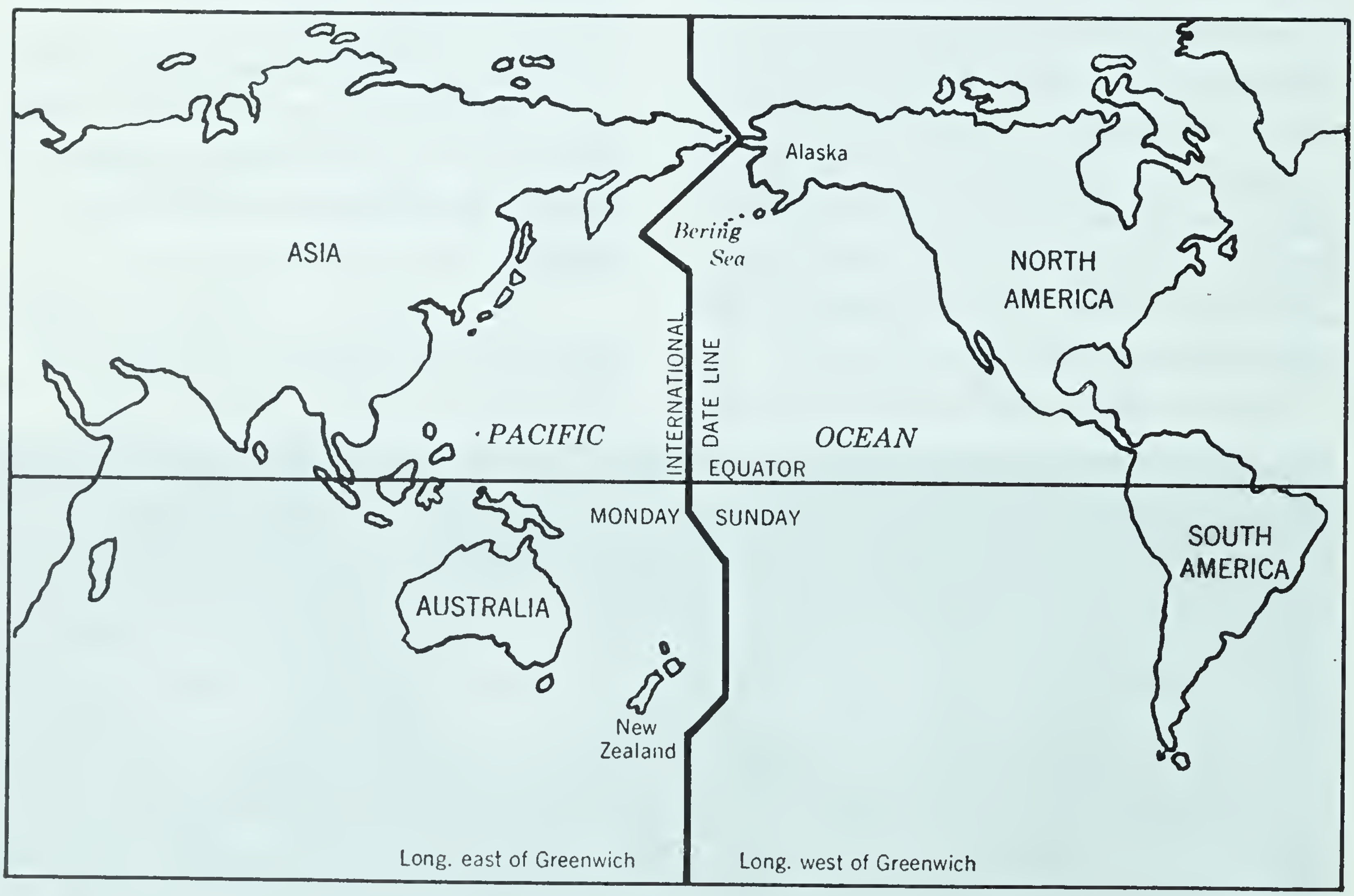


Fig. 8-35. The International Date Line is located at 180° longitude, east or west, depending on which way you travel from Greenwich, England.

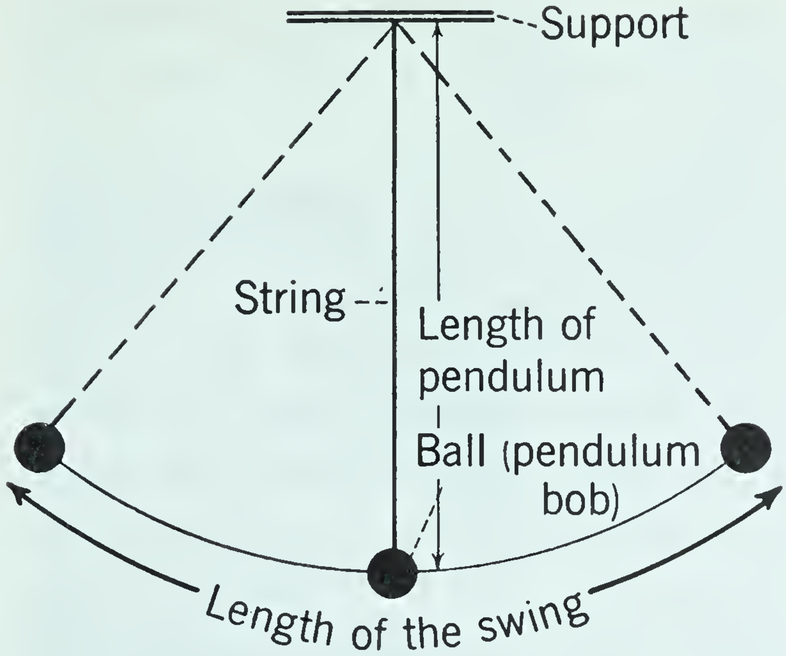


Fig. 8-36. Length of the pendulum is the only factor which determines the rate at which it swings.

DEMONSTRATION

Fasten a thin wire to a metal ball as in Fig. 8-36. Suspend the ball from some fixed support. Set the ball swinging a short distance. How many swings does it make in one minute? Give the ball a longer swing. Results? Shorten the pendulum. Does it swing slower or faster? Lengthen the pendulum. Now what are your results?

Use a ball of the same size but of different weight for the pendulum. With the same length of pendulum as before, that is, the same distance from the point of support to the center of the ball, discover what effect the weight of the pendulum has on the number of swings per second. Make a pendulum that swings once a second. How long is it?

The length of the arc and the weight of the pendulum have no effect on the number of swings per minute if the length of the arc is kept small. Length of the pendulum is the only factor that affects the rate at which it swings. The shorter the pendulum the faster it swings.

REVIEW QUESTIONS

1. What is latitude? In what ways can it be measured? **2.** What is longitude? How is it measured? **3.** What is the longitude of your locality? **4.** What is the difference in time between your locality and Greenwich? **5.** When it is noon at Greenwich, what is your time? **6.** Why is it necessary for navigators to know their latitude and longitude? **7.** What is the International Date Line? Why is it used? **8.** How can you use the pendulum to keep time? **9.** To what is the swinging action of a pendulum due?

G What causes the tides?

The tides are caused principally by the moon. Sir Isaac Newton first explained why all objects on the earth attract one another. His studies convinced him that an apple attracts the earth in proportion to its weight. In turn, the earth attracts the apple in proportion to its weight. We assume that all bodies on the earth also attract one another in proportion to their weights. We call the pull of the earth exerted on bodies *the force of gravity.* The measure of this pull is called the *weight of the body.* Scientists know that this pull, or force, exists between the earth and all other heavenly bodies. This universal pull is known as the *force of gravitation.* One of its many actions is seen in the tides.

A demonstration will help you to

understand what are the causes of tides.

DEMONSTRATION

Pour about a quart of water into a toy balloon. Fasten the neck opening tightly with rubber bands. Support the rubber ball of water in your left hand and give the neck of the balloon a sharp pull in a horizontal direction with your right hand. Result? Does the portion opposite that pulled with your right hand tend to remain behind?

Your right hand in the above demonstration represents the force of gravitation of a heavenly body on the earth. The body is the moon, which you have already learned is the nearest of the heavenly bodies to the earth. If it were twice as far away, the pull would be only one-fourth as great; three times as far away, one-ninth as great, and so on. This force of gravitation of the moon on any other heavy body on the earth becomes less and less as the distance away becomes greater. The sun also pulls on the earth, but it is so far away that the result is not as noticeable.

The waters on the earth are more movable than the solid land masses. Thus they react to this pull and form a ridge or hump on the side toward the moon.

The waters of the opposite side of the earth are, in a measure, left behind because of inertia. This causes a ridge of elevated water to appear also on the side of the earth away from the moon. These ridges of elevated water move around the earth as it revolves, forming the tides. The tides are really large waves which rise and fall against the shore. Rising tides are ***flood tides.*** Falling tides are ***ebb tides.***

Since the earth rotates once in 24 hours, it is easy to see why we have two high tides and two low tides each day. It is much as if the earth were rotating in a ring of water. A given point would meet the ring twice during each complete revolution. In tides, the water rises for about six hours and then slowly falls for the next six hours approximately.

When the sun and moon are pulling on the earth together, and in the same straight line, the highest and lowest tides occur. These are called the ***spring tides.*** When the moon and sun pull at right angles to each other, the tides are moderately high. These are called

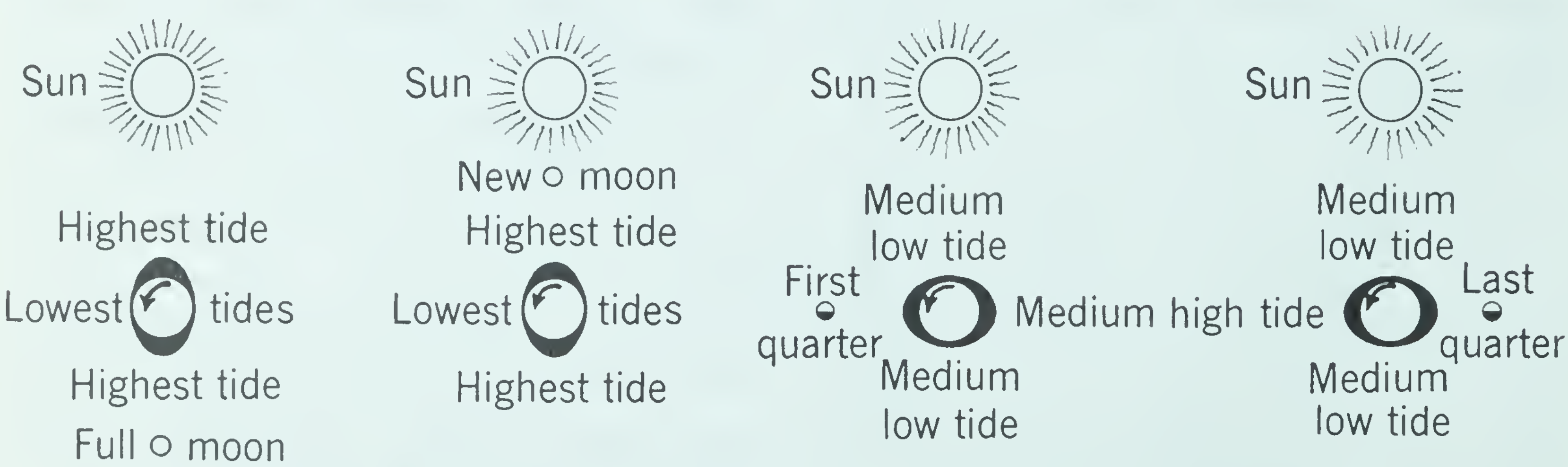


Fig. 8-37. The highest tides occur when the moon and sun pull on the earth in the same direction or in opposite direction. When do low tides occur?

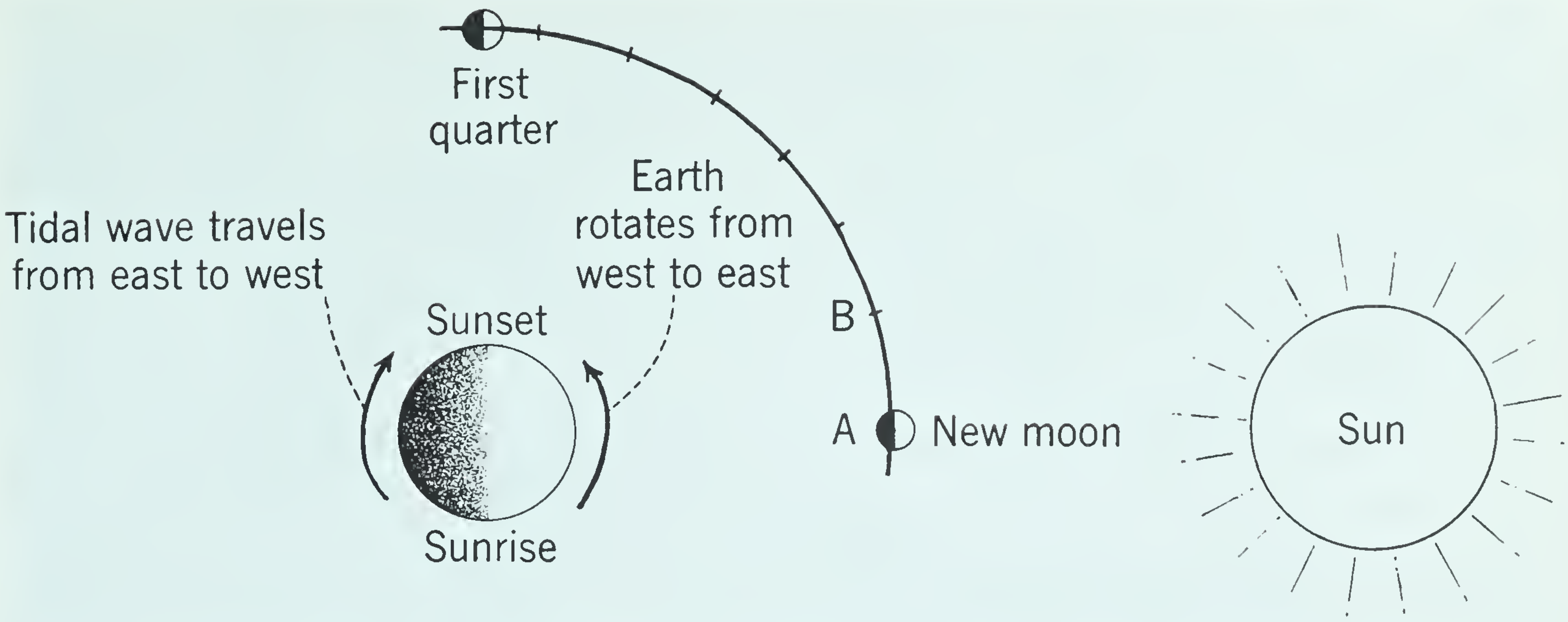


Fig. 8-38. By following this diagram with the text explanation, you can see why tides occur about fifty minutes later each day.

neap tides. The neap tides are not as high or as low as the spring tides.

The moon, though much smaller than the sun, has a far greater attraction than the sun for the water on the earth because the moon is nearer to the earth. When the sun and the moon pull in the same direction, the tides are the highest. When they pull at right angles to each other, thus pulling against each other, the tides are not so high.

Tides occur about fifty minutes later each day. You have probably noticed that high and low tides do not occur at the same times each day. This is because the moon changes its position every day.

PUPIL ACTIVITY

Observe the position of the moon for a few evenings at the same hour each night. Does this position constantly shift toward the east or toward the west? At the end of a lunar month, or 28 days, you will notice that the moon has successively changed its position until it is at the same place you began your observations.

Put an apple on a table to represent the earth. Let a small mirror represent the moon. Hold the mirror so that it constantly faces the apple, and move it about the apple. Note that the mirror revolves on its axis only once to keep the same side toward the apple during a complete circuit.

In the same way, the moon travels around the earth from west to east in 28 days. It rotates only once on its axis while it revolves once and thus keeps the same side always toward the earth. In the meantime, the earth rotates from west to east on its axis only once in every 24 hours. If the moon were stationary, it would, of course, rise much as the sun rises each day, but in the east. But since the moon is constantly traveling eastward, we have a problem that is somewhat like the following.

Suppose the moon is directly on our meridian at 9 P.M. During the next 24 hours the rotation of the earth on its axis will bring us directly back to this meridian. During the same time the

moon has traveled eastward $\frac{1}{28}$th of the distance needed to bring it to the same meridian at the same time, or 9 P.M. It will then take us $\frac{1}{28}$th of 24 hours to catch up with the moon or about 50 minutes. This happens each day. It explains why our high tides occur 50 minutes later each day.

The moon is held in its path by a combination of forces. Why does it not fall to the earth? You perhaps wonder why the heavenly bodies do not bump into each other as they move in their orbits around the sun, since the force of gravitation tends to pull all bodies together.

To understand why the comets, planets, satellites, and meteors continue in their orbits around the sun, we can use the following experiment.

PUPIL ACTIVITY

(To be done outdoors at a safe distance from buildings or people.) Tie some fairly heavy object firmly to the end of a piece of strong string. Whirl the object around your head and suddenly let go of the string. Does the object continue to move in a circular path? Partially fill a small bucket with water. Firmly hold on to the handle of the bucket and whirl it rapidly in a vertical circle. Does the water fall out?

These experiments demonstrate *centrifugal* (sen-*trih*-few-gal) *force.* This force tends to throw any rotating substance away from the center around which it rotates. It explains why mud flies off a bicycle wheel. It is the reason why rapidly spinning grindstones sometimes fly apart. It is also the basic principle in the spin-dry method used in many automatic washing machines. Can you think of any other appliances that use centrifugal force?

The bodies in the solar system are all moving at great speeds. If there were no other forces acting on them, they would move indefinitely in a straight line. But the force of gravitation tends to pull them all towards each other. The compromise between these two results in the nearly circular paths that most of these bodies follow.

These facts were first understood by Sir Isaac Newton. His *First Law of Motion* states "Every body continues in its state of uniform motion in a straight line, except insofar as it is compelled by force to change that state." You will perhaps recognize this as another way of stating the familiar principle of inertia.

You should now understand why the moon does not fall all the way to earth nor fly off among the stars. It is held in its path by the balance of two great forces: (1) gravitation which draws it toward the earth; and (2) inertia which tends to drive it straight out of the solar system. For the same reasons, the earth and all the other members of the solar family maintain their steady paths around the sun.

REVIEW QUESTIONS

1. What are the tides? What causes them? **2.** Why do tides occur about 50 minutes later each day? **3.** What are spring tides? Neap tides? Flood tides? Ebb tides? **4.** Why do mariners need to know when high tides and low tides occur? **5.** What is centrifugal force? **6.** What keeps the moon in its path? **7.** Why does the moon always keep the same side toward the earth?

Fig. 8-39. Tides are especially noticeable in narrow bays. Here, in the Bay of Fundy, boats rest on the mud and gravel at low tide. They will float alongside the dock when the tide comes in.

QUESTIONS FOR REVIEW AND DISCUSSION

1. When people thought the earth was flat, how did they explain night and day?
2. Why is the invention of the compass considered so important?
3. When was the earth first known to be a magnet with north and south magnetic poles?
4. Why do we say the sun is the center of our solar system?
5. What are the types of heavenly bodies in the solar system?
6. What causes night and day?
7. What causes the seasons?
8. What is a constellation?

9. What is the position of the North Star when a person is at the north geographic pole? How can you locate it where you live?
10. What is meant by a star of the first magnitude?
11. What is a light year?
12. How can a watch be used to tell direction?
13. How is a compass made? Why does a compass not point true north everywhere?
14. Compare the location of the earth's magnetic and geographic poles.
15. How do people at sea tell direction at night if the stars are visible? If they are not visible?
16. What is latitude? What is the latitude of your locality?
17. What is longitude? What is the longitude of your locality? Of the poles?
18. What is the approximate width of a time belt in degrees?
19. What is the difference in time between a point 90° west longitude and Greenwich? Is the time earlier or later?
20. What is a chronometer?
21. Why does Canada have different time belts? In what time belt do you live? What is the difference in time between your locality and Greenwich?
22. What scientific instruments are used to measure time, direction, latitude, and longitude? On what principle does each one work?
23. What factor determines the rate at which a pendulum swings?
24. What is the cause of tides? Under what conditions do spring tides occur? Neap tides?
25. What are some of the applications of centrifugal force?
26. In what ways would a space ship be like a modern rocket airplane?
27. What problems must be overcome before space travel is possible?
28. Why will establishment of a space station be easier than sending a rocket directly to the moon?

SPECIAL REPORTS AND PROBLEMS

1. Time-telling through the ages.
2. Interesting facts about the sun, planets, and moon.
3. Give the history of the compass.
4. Make a sundial.
5. The gyrocompass.
6. The earth-inductor compass.
7. The navigation instruments used by Admiral Byrd at the South Pole.
8. Stories about the constellations.
9. Report on one of these great men of astronomy: Galileo, Ptolemy, Copernicus, Brahe, Kepler, Newton.
10. The story of the Mt. Palomar telescope.
11. Different types of telescopes.
12. Make a model of a space ship.

13. Write an account of an imaginary trip to the moon.
14. Report on science fiction stories in books and on radio and television, with special emphasis on their scientific accuracy.

TESTING THE PURPOSES OF THIS UNIT

1. What is the definition or meaning of each of the following words or terms: star, planet, moon, eclipse, constellation, comet, meteor, season, compass, latitude, longitude, sextant, quadrant, chronometer, declination, meridian, equator, time belt, pendulum, centrifugal force, tide, International Date Line, light year, magnitude of a star, satellite, solar system, astronomy, corona, acceleration, centrifuge?
2. Is the earth flat or round? How can you prove your statement?
3. If a group of boys planned a trip around the world in a sailing boat, what instruments would they need to guide them? What astronomy would they need to know? What facts would they need to know about the earth?
4. What has science contributed to developing methods of guiding people in their travels? What instruments have been developed for this purpose?
5. How do aviators get direction and distance when flying long distances over water? Why is one of the men on these flights usually a navigator?
6. Why is it difficult for aviators to fly in heavy fog? What suggestions do you have to offer for overcoming their difficulties?
7. What is done to prevent ships at sea from running into each other during heavy fogs?
8. Compare navigation and travel in early times with those of the present time. In what ways are they alike? Unlike?
9. How has the telescope helped to place the study of astronomy on a scientific basis? How has the telescope helped man to overcome the superstitious beliefs of ancient times?
10. Many people believe that astronomy has little practical value because the heavenly bodies are so far away. The scientific study of astronomy has led to many practical applications for people living on the earth. Explain how the increased knowledge of the heavenly bodies has:
    a. Aided navigation and world exploration.
    b. Helped in understanding the causes and lengths of seasons in different parts of the earth.
    c. Explained the nature and causes of tides and the time at which tides will occur.
    d. Helped to tell time accurately.
    e. Made possible the discovery of new elements. Helium was discovered in the sun before it was discovered in the earth's atmosphere.
    f. Predicted the possibility of atomic energy. It is believed that the stars are kept hot by atomic energy.
    g. Made possible the development of accurate methods of measurement.

11. There have been four stages in the development of the scientific method. They are:
   A. Superstitious belief or fear stage.
   B. Authoritative opinion stage. Definitions are in this stage.
   C. Observation stage.
   D. Controlled experiment stage.
   In which of these stages is each of the following statements best placed?
   1. The earth is flat.
   2. The sun is the center of the solar system.
   3. The sun is a star.
   4. The earth turns on its axis 15 degrees each hour.
   5. The shorter the pendulum the faster it vibrates.
   6. The weather on the earth is affected by the moon.

12. If you have an automatic washing machine, observe the position of the clothes at the end of the spin-dry cycle. Can you explain your observation?

13. Early navigators could determine latitude fairly well, but their calculations of longitude were often inaccurate. Can you see any reason why they had so much more trouble with the determination of longitude?

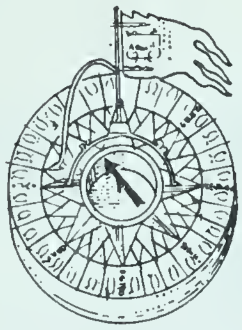
14. How has aviation contributed to the possibility of space travel?

15. Why could we not use present day aircraft for space travel?

16. How would it be possible to duplicate the conditions in outer space here on the earth's surface?

17. The questions which follow refer to the earth.
   a. Express in hours the length of time it takes it to rotate on its axis.
   b. What is the number of degrees in a circle or complete rotation?
   c. What is the number of degrees the earth rotates in one hour?
   d. What is the earth's circumference in miles at the equator?
   e. How many miles does the equator's surface move in one hour? In one minute?
   f. What is the season of the year when it is nearest the sun? Farthest away?
   g. What two days in the year does it have days and nights of equal length?
   h. In what day of the year does the northern hemisphere have its longest day?
   i. What is the longitude at Greenwich, England?
   j. If it is noon at Greenwich, England, what is the time at a place 90° west longitude? 90° east longitude?
   k. If you are at a place 75° west longitude and travel to a place 105° west longitude, will you set your watch ahead or back? How many hours should it be changed?
   l. How many degrees is the earth tilted on its axis?
   m. At what season of the year is the northern hemisphere tilted toward the sun?
   n. At what season of the year is the earth nearest the sun? Farthest away?
   o. How long does it take light to travel from the sun to the earth?
   p. How does sunlight reach the earth from the moon?
   q. What is the earth's latitude at the equator? At the North Pole? At the South Pole?

The old



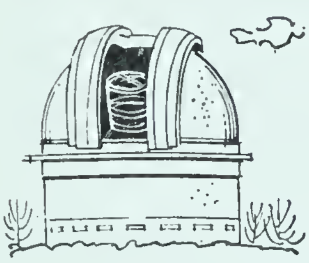
BEFORE THE INVENTION OF THE COMPASS, DISTANT TRAVEL on unmarked routes was difficult and uncertain. With the invention of the compass, however, travelers began to explore new lands and seas. With the invention of navigational instruments, it became possible to tell direction and location more accurately.

At one time, people had to depend on the sun to tell time. Then the invention of the clock, based on the principle of Galileo's first clock, was used for that purpose.

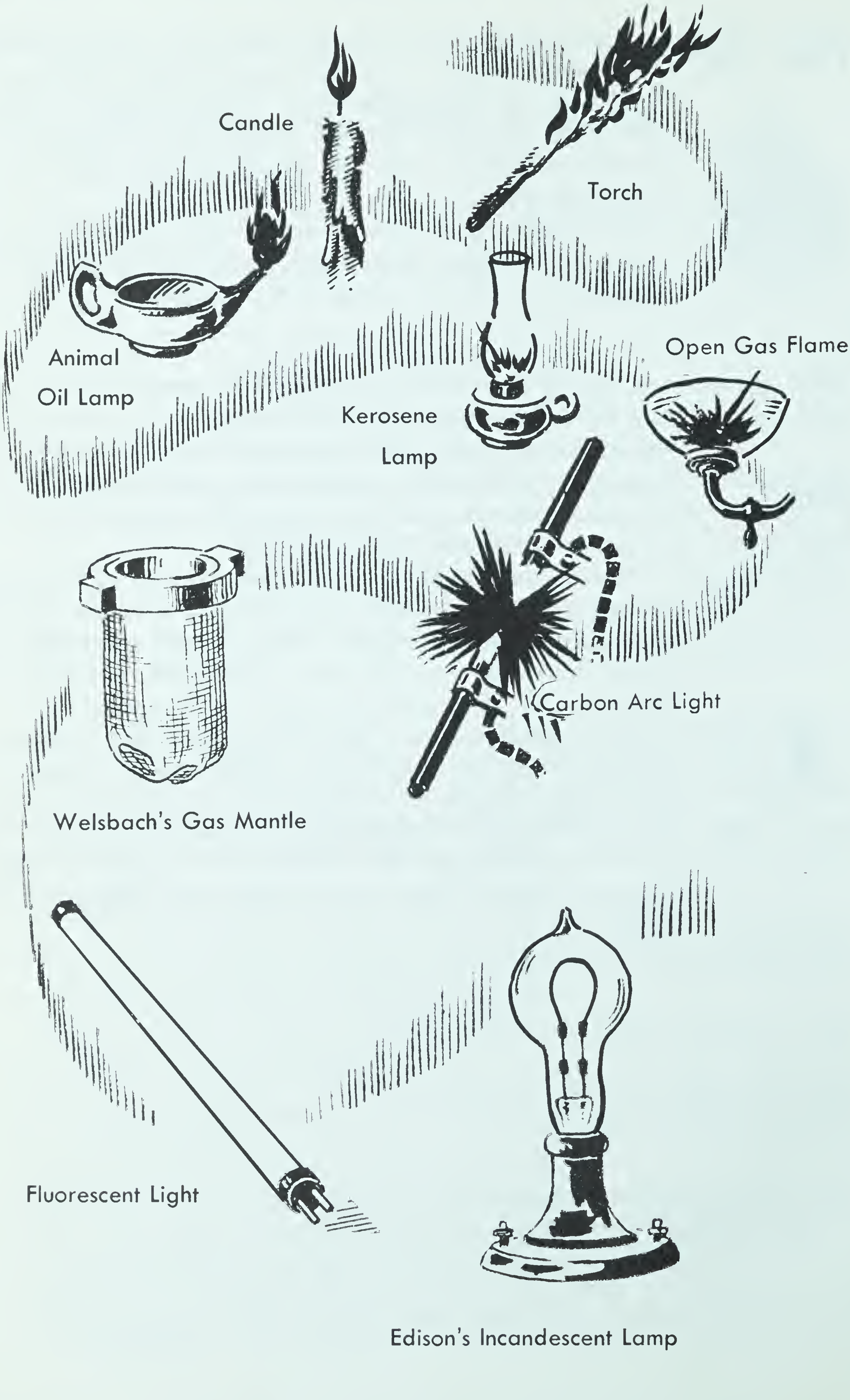
The new

AT THE PRESENT TIME, PILOTS AND NAVIGATORS OF SHIPS and aircraft can find their positions almost as accurately as people on land. New apparatus already in use and being constantly improved makes it possible for planes and dirgibles to fly across all parts of the earth with safety, insofar as direction, distance, and location are concerned.

The scientist hopes he will be able to get a better understanding of the universe through observation made with the new telescope at Mt. Palomar. The new radio telescopes may reveal facts that we cannot learn through the ordinary telescopes.



Just how do the stars like the sun give off a continuous supply of heat energy? Will the supply remain constant? If the supply of heat is decreasing, how long will the heat energy last? If the way heat is produced in the sun is understood, will it help in developing new sources and new uses for atomic energy? These are some of the problems the scientists hope to solve.


Candle
Torch
Animal
Oil Lamp
Kerosene
Lamp
Open Gas Flame
Carbon Arc Light
Welsbach's Gas Mantle
Fluorescent Light
Edison's Incandescent Lamp

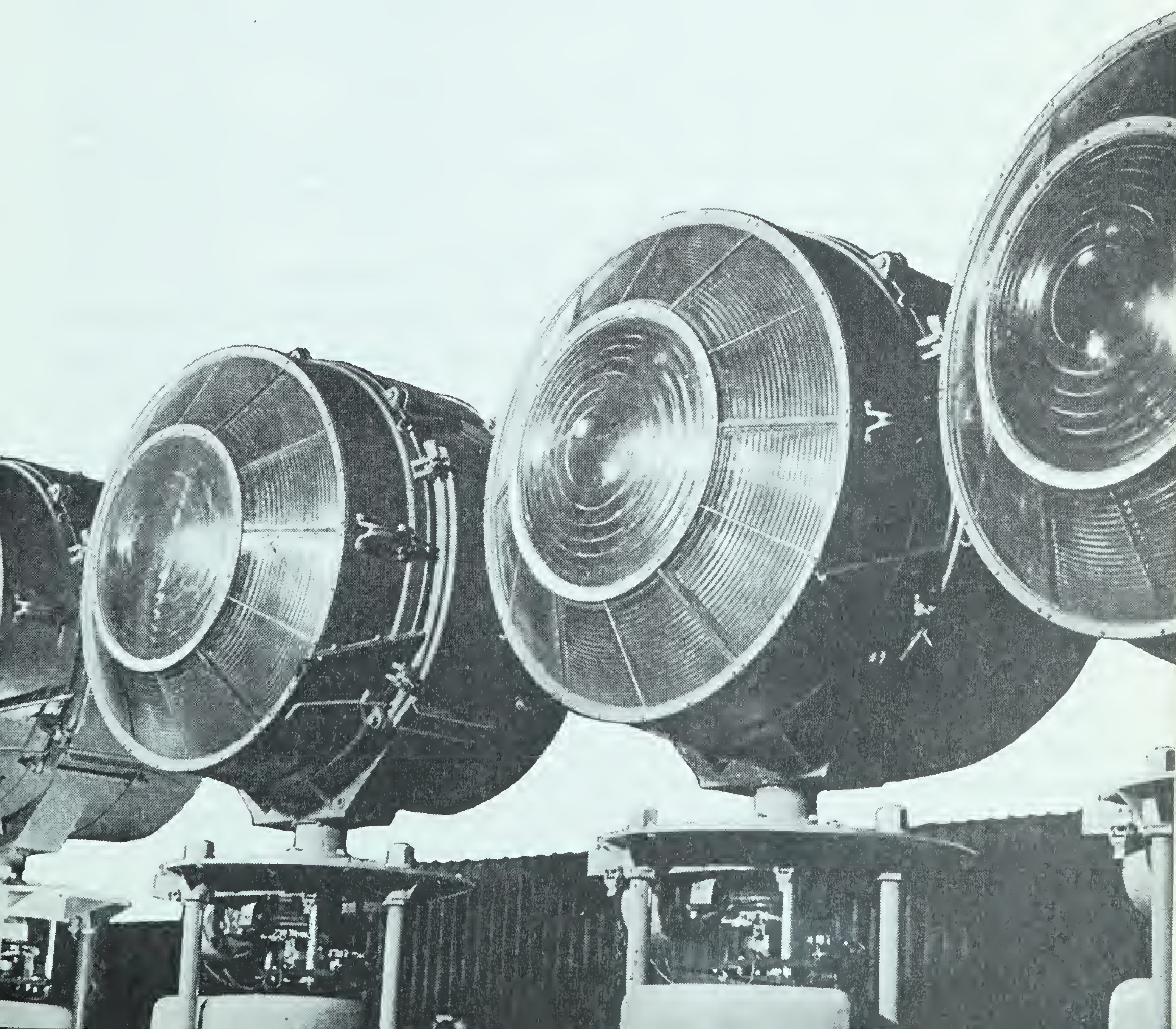
UNIT 9

How has man learned the nature and uses of light?

DISCOVERY AND PROGRESS

THE people of ancient times were sun worshippers. Light represented good to them, while darkness represented evil. Since the moon and stars gave off light, they also held these heavenly bodies in awe.

Early man had to stay at home most nights because he had no way to see in the dark. When he discovered how to



control fire, he used wooden torches. Then he learned that he could add animal fats to the torches to make them burn brighter. Finally, he burned the fats alone in stone or metal lamps. The invention of the wick greatly improved the lamps. Open gas flames were also used for light. Welsbach's gas mantle improved the efficiency of the gas flames by producing white light.

Further progress in illumination was made with the development of the carbon arc, which gives off very brilliant light. This is still used in spotlights.

In 1879, Thomas Edison found that he could carbonize ordinary cotton thread. He sealed this thread in a glass bulb from which the air had been exhausted. Then he caused an electric current to flow through the bulb and the thread became brilliantly lighted. This was due to the intense heat. With this invention came the first practical use of the *incandescent* (in-kan-*deh*-sent) *lamp*. In 1907, scientists substituted tungsten for carbonized thread. In 1913, they found that by filling the bulb with certain gases, they could make the filament burn longer. Our modern electric lights have been developed from this lamp.

Probably the first telescope was invented by Hans Lippershey, a Dutch spectacle maker. It is said that an apprentice in his shop put two eye glasses together in a long tube, and amused himself by looking at a distant church spire. He was surprised to find that the weathervane on the spire appeared large and upside down. His instrument was soon used in warfare to spy on the enemy, and the story of the spyglass spread rapidly.

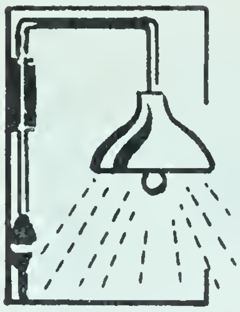
The first microscope was made sometime during the 16th Century. Galileo has been credited with it. However, two Dutch brothers, Johann and Zacharias Janssen, made the first practical microscope about 1590. This instrument has made it possible for man to study tiny organisms.

Sir Isaac Newton demonstrated the composition of white light in 1672, thus explaining the mystery of color. Light is separated into the rainbow colors when it passes through a glass prism. About 200 years later, Bunsen discovered that he could tell the chemical elements in a flame by letting its colored light pass through a prism.

"I have seized the light. I have arrested its flight! The sun himself in the future shall draw my pictures!" said Louis Daguerre, a French painter and physicist. The reason for these words was his discovery of how to make photographic plates. By 1840 he had made the first photographs.

At the present time, the study of methods of lighting and proper illumination is a science in itself. Lighting engineers consider whether direct, semidirect, or indirect lighting should be used. They are concerned with the proper kind and coloring of shades, walls, and hangings. Such lighting, constantly being improved, makes for more comfortable and healthful living.

The problem of increasing the efficiency of our lighting methods is still to be solved. Science will surely find ways to improve them.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How does light reach the earth from the sun? **2.** What are shadows? **3.** What are eclipses and how are they formed? **4.** How does the sun heat greenhouses and sun porches? **5.** Does light travel in straight or curved lines? **6.** How do rough and smooth surfaces affect rays of light? **7.** What is an image? **8.** Why are objects under water not in the position in which they appear to be? **9.** What is a convex lens? **10.** How do concave lenses affect rays of light? **11.** What makes objects appear colored? **12.** How does the human eye function? **13.** How are pictures taken with a camera? **14.** What different forms of artificial lighting has man used?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

candle power . the amount of light given out by an object compared to the light from a standard candle.

concave lens . (kon-*kave*), a lens which is thinnest in the middle.

convex lens . . (kon-*vecks*), a lens which is thinnest at the edges.

foot candle . . the light intensity at any given point one foot from a standard candle.

incandescence (in-kan-*deh*-sense), the glowing of materials caused by intense heat.

incident rays . rays of light striking a surface.

luminous . . . . giving out light.

opaque objects (oh-*pake*), those that do not let light pass through them.

penumbra . . . (peh-*num*-brah), the lighter part of a shadow.

reflected rays . rays of light bouncing off a surface.

sun spectrum . a band of colors formed by a beam of sunlight passing through a prism.

translucent . . (trans-*lew*-sent), letting some light pass through.

umbra . . . . . . (*um*-brah), the dark part of a shadow from which all direct light rays are cut off.

A How does the sun's energy reach the earth?

We get heat and light from the sun. But how do they reach us? It cannot be by conduction, since there is little matter between us and the sun. And the sun is 93 million miles away! It cannot be by convection either, since there is no matter to circulate.

Heat and light from the sun reach us by *radiation.* Radiation, in the form of vibrations or ripples, spreads through space in all directions especially noticeable from any hot or lighted body. When the vibrations strike the earth's surface or any object, they set the molecules they touch into more rapid vibration, thus giving them heat. Some of these radiations affect the eye, and we call them *light.* When objects glow, they send out *light waves* which vibrate rapidly. *Heat waves* vibrate more slowly. This difference in frequency of vibration causes the difference between heat and light.

Some substances let light waves pass through them more easily than heat waves. You probably know that light waves pass through glass more easily than do heat waves. But is it possible to absorb light waves and heat waves and prevent the heat from escaping?

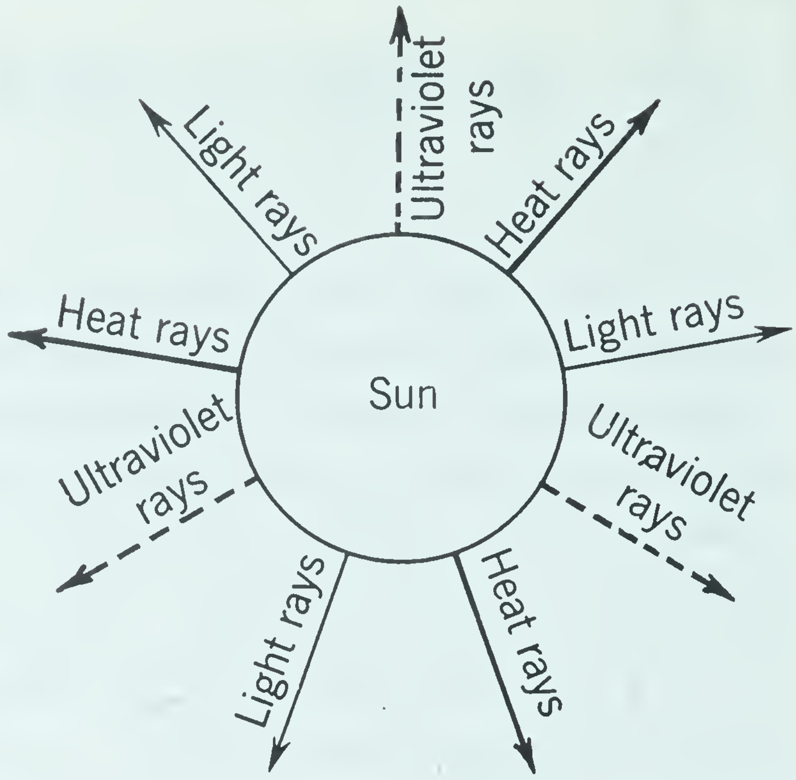


Fig. 9-1. The rays of the sun radiate in all directions.

DEMONSTRATION

Put some black soil into a box (see Fig. 9-2). Put one thermometer inside the box and another outside the box. The thermometers should have approximately the same reading. Put a glass cover on the box. Now put the box and cover in a position where the sun's rays will pass through the glass and into the soil. Take the readings of the thermometers every five minutes for at least 30 minutes, longer if necessary. What are the results? How are cold frames heated? What are they used for?

Evidently the radiant energy from the sun passed through the glass. It was absorbed and made the soil warmer. The heat from the soil does not pass through glass easily. Therefore, heat accumulates in the box and the temperature rises. Such a box is called a *cold frame.* A cold frame is heated only by radiation from the sun, never by artificial heat. Some greenhouses and sun porches are heated in the same way.

The air and clouds act much the same as the glass of greenhouses or sun porches. Light and heat waves pass

through the air and strike the earth, which absorbs some of them. The earth is heated by this absorption. Then the heat radiates from the earth, but these heat waves from the earth do not pass through air as easily as light waves and heat from the sun do. Hence much of the heat remains near the earth.

Heated objects, fires, and sources of artificial light set free radiant energy. You have already learned that heat energy travels from a heated object to your body. You can see fires some distance away, but unless you are close to them, you do not feel the heat. An electric light radiates both heat and light. While it is used mostly to produce light, it gives off a large amount of energy in the form of heat, too.

As you move away from a heated object, the amount of heat that you receive decreases. As you move away from a source of light, there is also a decrease in the intensity of light received. However, the change is more rapid with heat. You can see the light from a lamp for long distances, but you can only feel its heat for a short distance. Light energy, then, passes through the air with less loss than heat energy.

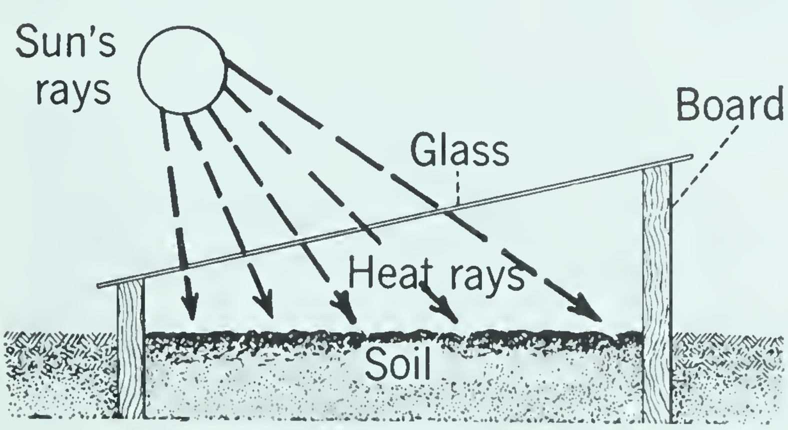


Fig. 9-2. The soil in a cold frame is heated by radiation from the sun.

REVIEW QUESTIONS

1. Compare light and heat waves. **2.** How is a cold frame made? **3.** How are greenhouses and sun porches heated? **4.** How is the earth heated? **5.** How does heat energy travel from the sun to the earth? **6.** How is the earth's atmosphere heated? **7.** Why are some cloudy days cooler than days on which the sun shines brightly? **8.** Why is it colder at the top of a mountain than in a valley below?

B How are shadows and eclipses formed?

Light travels in straight lines. A single line of light is a ray. We call several rays a *beam of light*. Objects that do not let light pass through them are *opaque* (oh-*pake*). Substances that do let light pass through them clearly are ***transparent***. For example, wood is opaque, but clear glass is transparent. Frosted glass is ***translucent*** (trans-*lew*-sent), which means that some light passes through it but objects cannot be seen through it distinctly.

PUPIL ACTIVITY

Set up three 8 inch squares of cardboard with holes in their centers and a candle, as in Fig. 9-4. Arrange the cardboards so that you can see the candle flame through the holes. Move one cardboard slightly toward either side. Can you now see the candle flame? In what position must you

Fig. 9-3. In greenhouses seedlings and cuttings can be started well ahead of spring.

put the holes so that you can see the flame through them? Did the light take a straight or a curved path?

You have learned by experience that light travels in straight lines. You know the location of objects because light comes from them to you in a straight line. You use this fact when you sight a gun. But light rays are bent when they pass obliquely from air into water or from water into air. That is why it is hard to locate objects under water.

Sharply marked shadows form when the source of light is relatively small. You have noted that your

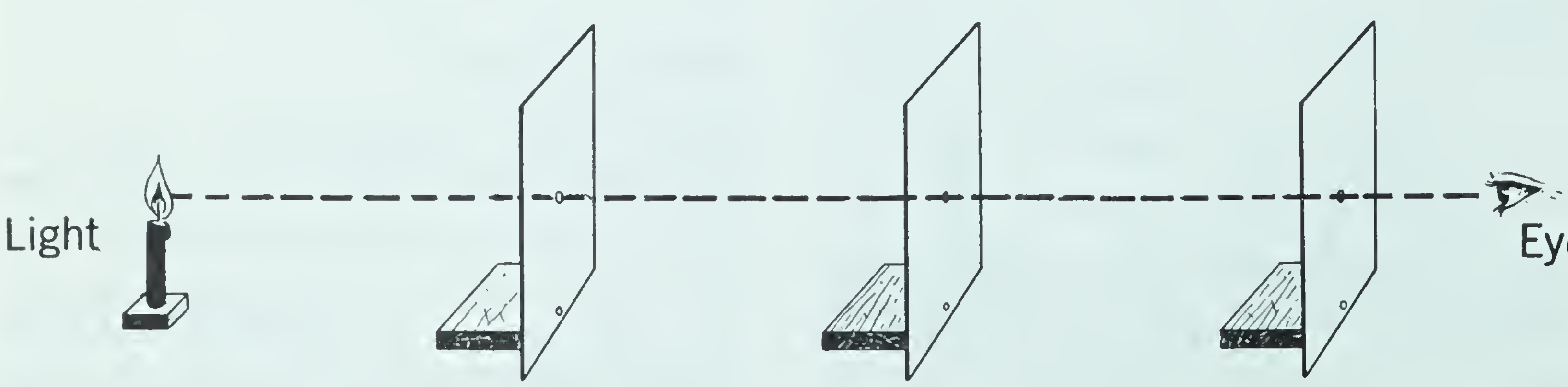


Fig. 9-4. As you can see from this demonstration, light travels in a straight line.

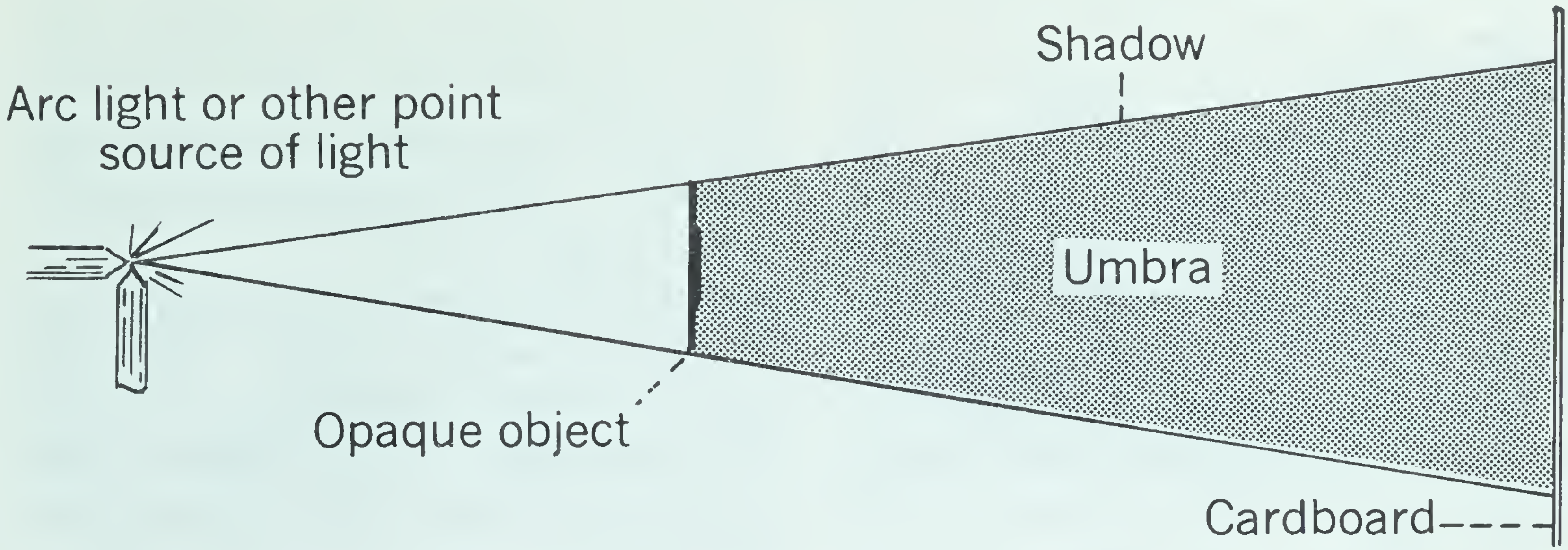


Fig. 9-5. When the source of light is small, sharply marked shadows are formed.

shadow forms when you stand near a concentrated light, especially in a darkened room. Under what conditions are shadows formed? Have you observed that sometimes shadows are lighter on the edges than in the center? How does this happen?

DEMONSTRATION

First use a very small source of light. Make a small hole in a piece of tin or heavy cardboard. Fold it around a candle flame or an electric light bulb. Darken the room as much as possible. Hold a cardboard about a foot square two or three feet from the source of light. Let rays of light from the small hole shine on the cardboard. Is the cardboard lighted up?

Now put a small cardboard about two inches square between the source of light and the larger cardboard. Is a shadow formed? Now change the distance between the light and the opaque object. Result? Next, move the cardboard toward the opaque object. Result? What are the differences in the shadows formed?

Study the diagrams in Figs. 9-5 and 9-6 to see how the shadows are formed.

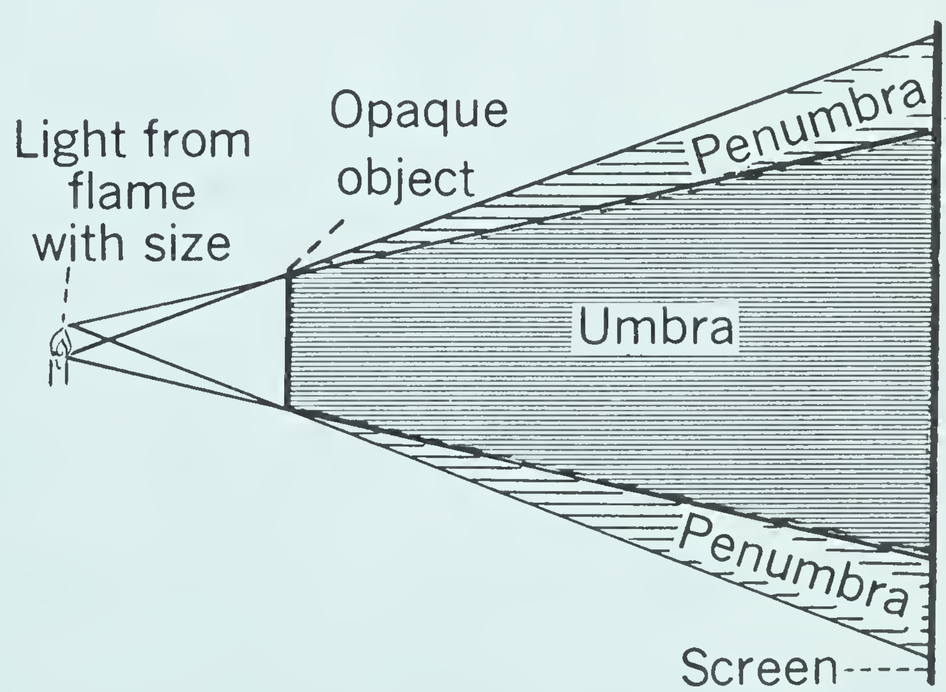


Fig. 9-6. When the source of light is larger than in Fig. 9-5, shadows with shaded edges are formed.

The dark part of the shadow from which all direct rays of light are cut off is the *umbra* (*um*-brah). The lighter, or outer, part is the ***penumbra*** (peh-*num*-brah). Some of the rays of light are cut off from this part of the shadow.

Eclipses of the sun and moon are shadows. Your understanding of how shadows are formed will help you to explain eclipses of the sun.

You have already learned that the moon revolves around the earth, and at regular times passes between the sun and the earth. At certain other times, the earth is between the sun and the moon.

Study Fig. 9-8. When the moon is in position 1, it casts its shadow on the earth. Because the shadow is smaller in diameter than the earth, only small areas of earth are in the umbra. People in that area see a total eclipse of the sun. Those in the other parts of the earth see either a partial eclipse or none at all.

When the moon is in position 2, it is in the earth's shadow. Since the earth's shadow is greater in diameter than the moon, a total eclipse of the moon can be seen from large areas on the earth.

REVIEW QUESTIONS

1. How does light travel? **2.** What is a shadow? **3.** How is a shadow formed? **4.** Under what conditions is an eclipse of the sun formed? An eclipse of the moon? **5.** Why is it that eclipses of the sun are seen only from limited areas of the earth? **6.** How is it possible to have a shadow with an umbra and without any penum-

Fig. 9-7. The formation of shadows proves that light travels in a straight line.

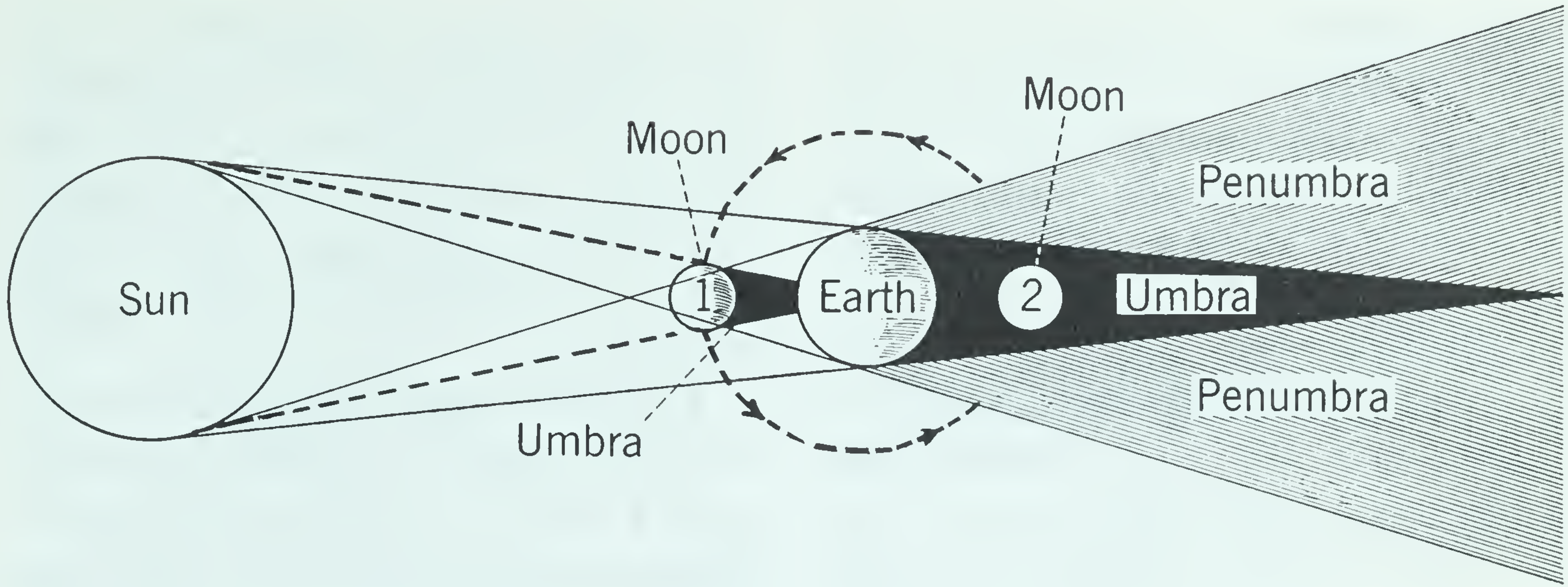


Fig. 9-8. What happens when the moon is in position 1 in this diagram? Explain also what happens when the moon is in position 2.

bra? **7.** How is the size of your shadow affected by moving nearer the source of light? **8.** What is the meaning of the words: (a) transparent, (b) opaque, (c) translucent?

C How do we use reflection of light?

Images are formed by reflection of light from smooth surfaces. *Reflection* is the "bouncing back" of rays of light. If you stand in front of a mirror, you can see your image, but not if you stand in front of a wall. What makes the difference? You may think that the mirror reflects light and the wall does not. However, both the mirror and the wall reflect light, and both absorb light.

DEMONSTRATION

Light a candle. Hold the flame near, first, a sheet of paper; second, a blackboard; third, a mirror; fourth, a piece of glass; fifth, a plastered wall; sixth, a painted surface; seventh, a tall glass dish filled with water. Which surfaces form a clear image of the candle? Which surfaces do not form a clear image of the candle? Feel the surfaces. Which are rough? Which are smooth? Did the rough or smooth surfaces form the best images?

When rays of light strike glass, some are reflected, some are absorbed, and some pass through (see Fig. 9-9). If they strike a *rough surface,* some are absorbed and some are reflected, but few pass through. Light rays striking a smooth surface, such as a mirror, bounce off at an angle equal to the angle they made when hitting the mirror (see Fig. 9-9).

Rough surfaces diffuse light. The walls of a room are usually made rough to diffuse or scatter the light that strikes them. This reduces glare.

Light reaching the earth is also diffused. Some rays are changed in direction as they are reflected from dust particles in the air, from the earth, and from objects on it.

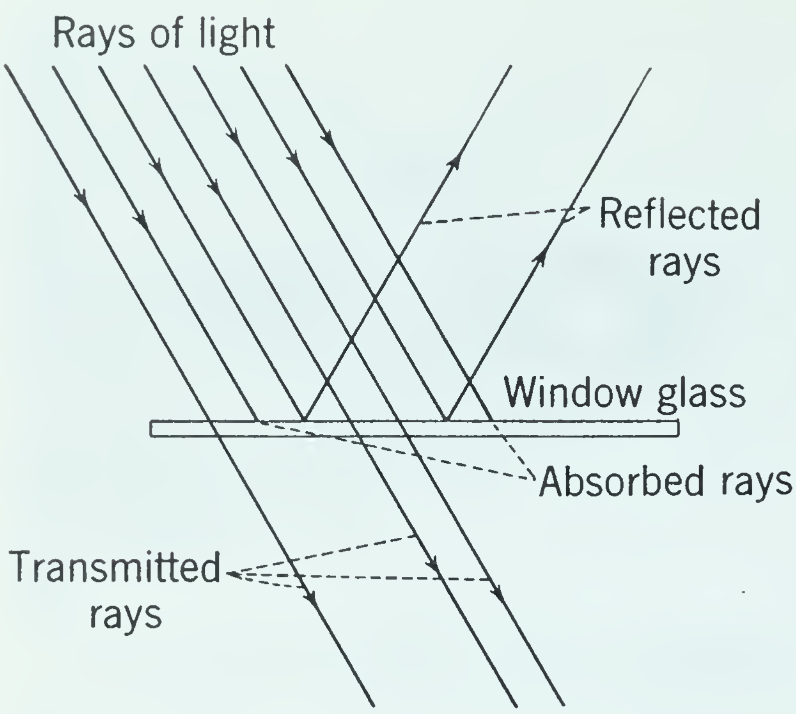


Fig. 9-9. Glass transmits, absorbs, and reflects rays of light.

Rays of light striking a rough surface are reflected in all directions. We call this ***diffusion*** (dif-*you*-shun). Most of the daylight we see is diffused. Images are formed by reflection from smooth surfaces because all the rays tend to leave the surface at the same angle, equal to the angle they made as they arrived. (See Figs. 9-9 and 9-10.)

Images in a plane mirror are erect and reversed. A *plane mirror* is an ordinary flat mirror.

PUPIL ACTIVITY

Stand in front of a plane mirror. Where does your image appear to be in the mirror? While looking in the mirror, raise the hand that appears to be the right hand of your image in the mirror. Which hand did you raise? Are images in a plane mirror inverted or erect? The same or reversed? If you have a photograph of yourself, compare it with your image in the mirror. Does your mirror image look different from your photograph? Can you explain why?

An image appears to be as far back of a plane mirror as the object is in front of it, and it is reversed. That is, the right side appears where the left side is, or vice versa. Your image in a mirror appears to face you. The object and image are facing in opposite directions.

Light rays strike and leave a mirror at equal angles. You have probably used a mirror to reflect rays of light to different parts of the room. And you have certainly looked at your back by means of a set of mirrors. A submarine periscope uses mirrors so that an observer under water can see what is going on above the surface of the water. Can you think of any other ways in which periscopes are used?

The rays of light striking a mirror are *incident rays.* Those that leave a mirror are *reflected rays.* Let us try the following experiment to help understand how rays of light strike and leave a mirror.

PUPIL ACTIVITY

Put a mirror on a table with the reflecting surface facing you. Where must you stand to see your image in a mirror? Try several different positions. Draw a straight line on a sheet of paper and put

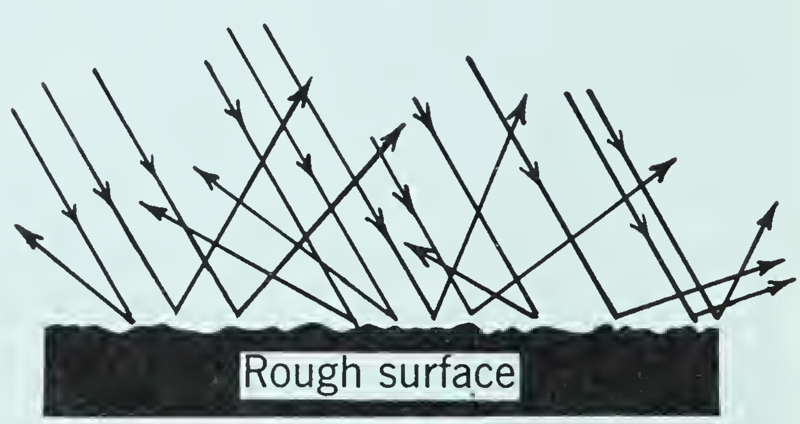


Fig. 9-10. When rays of light strike a rough surface, they are diffused or scattered.

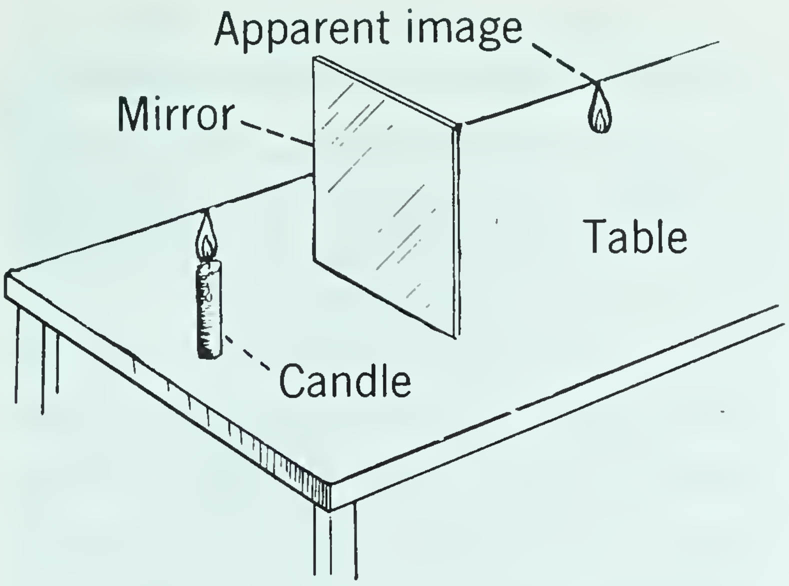


Fig. 9-11. The apparent image in a plane mirror is behind the mirror.

the line at an angle with the mirror. Where does the image of this line appear to be in the mirror? Draw a line which appears to be in a straight line with the image of the first line in the mirror. Which is the incident ray? Which is the reflected ray? Where must you stand to see the image of an object in a mirror when the object is placed toward one side of the mirror?

To see your image in a mirror, you had to stand directly in front of it. Light reflected from your body to the mirror was reflected back to you again. When you stood toward the side of the mirror, the light was reflected away from you so you could not see your own image. When light rays strike a mirror, the ***angle of incidence*** is equal to the ***angle of reflection*** (see Fig. 9-12). This is also true for objects which diffuse light; but because there are so many different planes, no image can be formed.

We make use of this fact in painting walls and ceilings. Paint with a rough surface diffuses the light that reflects from it, as shown in Fig. 9-10. Glossy paint produces a glare because of its smooth surface.

Mirrors may also have curved surfaces. Up to this point we have mentioned only flat, or *plane mirrors.* A *concave* (kon-*kave*) *mirror* is curved away from you toward the center, and thus can be used to bring light rays to

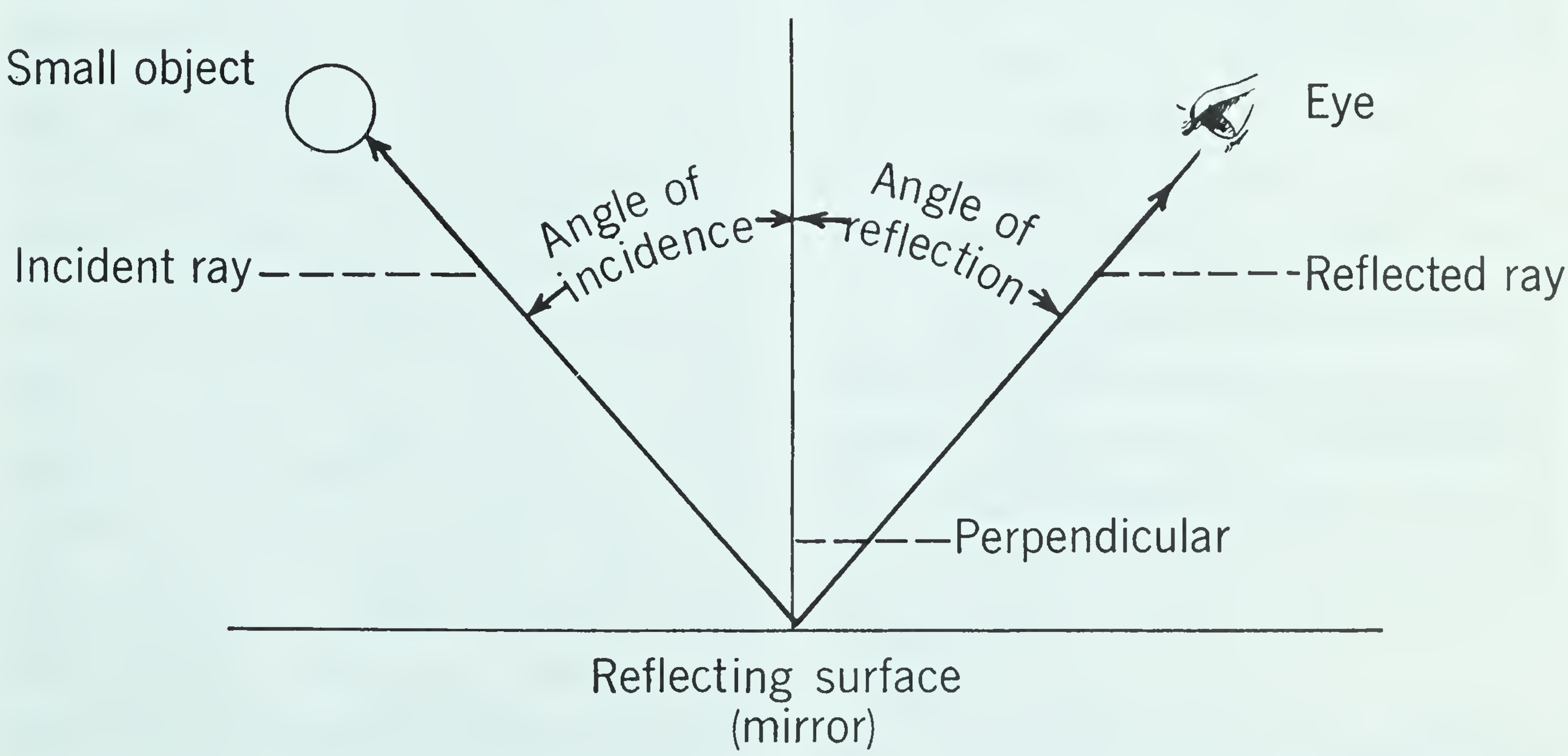


Fig. 9-12. When a light ray strikes a mirror, the angle of incidence and the angle of reflection are equal.

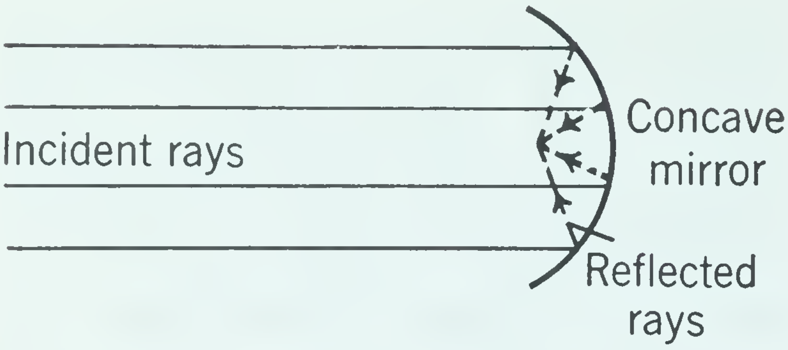


Fig. 9-13. A concave mirror curves inward and brings light rays to a focus. The telescope in Fig. 8-17 on page 218 uses a concave mirror.

a focus. This is explained in the diagram Fig. 9-13.

The largest telescopes, such as the 200-inch one at the Mt. Palomar observatory, use concave mirrors to bring light rays to a focus. They are called ***reflecting telescopes.*** Concave mirrors are also used in spotlights and floodlights. If you examine an automobile headlight or a flashlight, you will see how such mirrors are used. Those of you who use flash cameras are familiar with the concave reflector which is used for the purpose of concentrating light in a limited area. Can you think of any other ways in which concave mirrors are used?

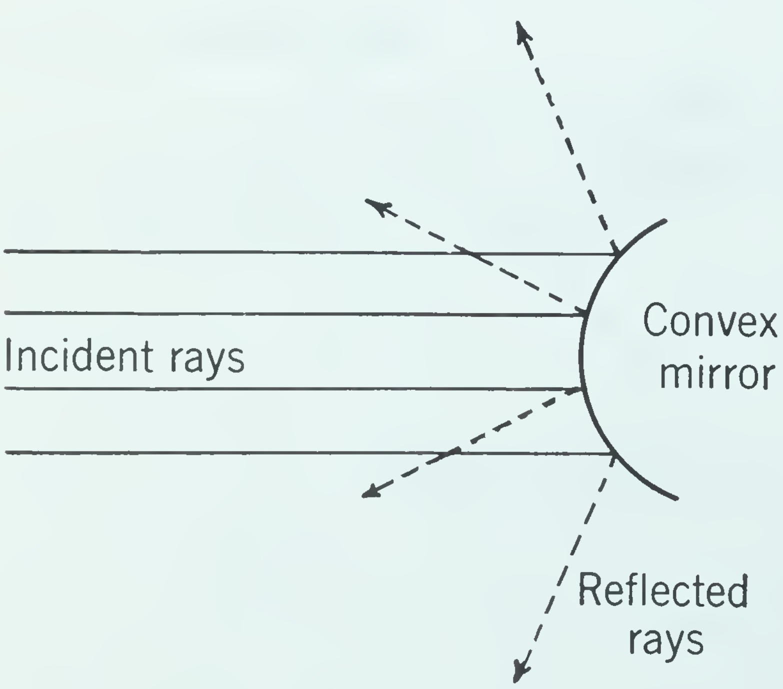


Fig. 9-14. A convex mirror curves outward. For what purposes is it used?

A ***convex*** (kon-*vecks*) ***mirror*** is quite different from a concave mirror. A convex mirror is one which bulges outward. It cannot be used to focus light rays. You can see why by studying the diagram in Fig. 9-14. Convex mirrors have little practical value although they are often used for ornaments in homes and gardens. Convex rear view mirrors are used in automobiles, buses, and other motor vehicles. They give a wider field of vision, but make it difficult for the driver to judge the distance of approaching vehicles.

You have probably visited an amusement park at some time. If so, you no doubt have seen a "fun mirror." Such a mirror produces a distorted image because its surface is curved irregularly. Can you think of other uses of curved mirrors?

REVIEW QUESTIONS

1. What kinds of surfaces are used to form images? **2.** How is light diffused? **3.** Compare objects and the images they form in a mirror. **4.** Where must you stand to see objects in a mirror? **5.** What is the incident ray? What is the reflected ray? **6.** What are the angles of incidence and reflection? Compare their size. **7.** What is meant when it is said that the image is reversed? **8.** What three things happen to rays of light when they strike a piece of glass? **9.** Why must you stand directly in front of a mirror if you want to see your own image? **10.** How are curved mirrors used? **11.** Give several observations to prove the fact that light travels in straight lines. **12.** How does energy from the sun travel through space to the earth?

D How are light rays affected when they pass through glass or water?

The bending of rays of light is called refraction. You probably have used a lens as a burning glass or have used a reading glass to make print appear larger. And you have pushed a stick into water and noticed that it appeared to be bent. How is the direction of light waves changed when they pass from air into glass, water, or other transparent substances?

DEMONSTRATION

Fill a glass nearly full of water. Put a ruler into it. Sight along the ruler into the water. How does the part of the ruler under water look?

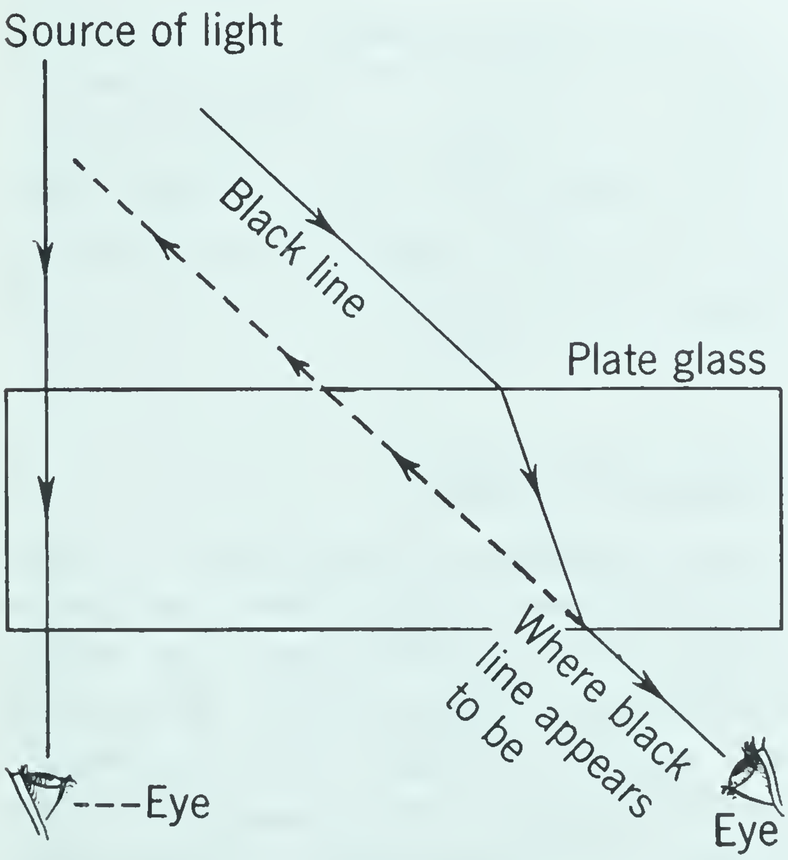


Fig. 9-15. A ray of light striking plate glass at an oblique angle is bent as it passes through the glass.

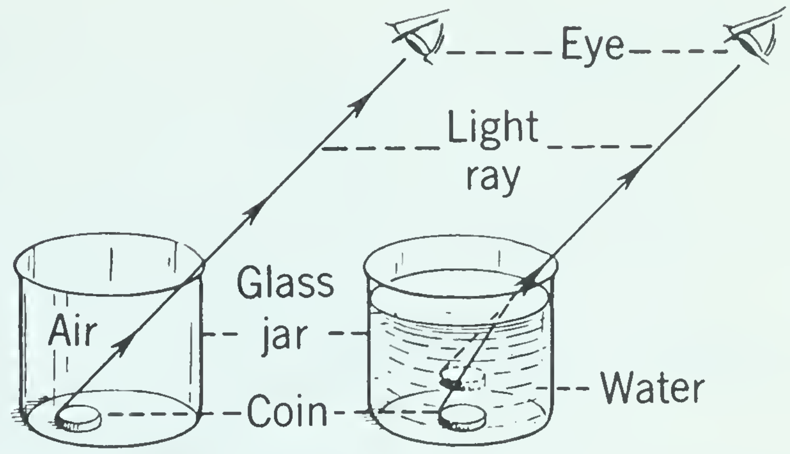


Fig. 9-16. Note that light rays are bent when they pass from air into water, or from water into air.

Draw a black line on a sheet of paper. Put a thick piece of glass over the paper so that the ends of the line project beyond the edges of the glass. Look straight down the line. Result? Now draw another line obliquely to the plate and repeat your observation. Result? See Fig. 9-15.

Drop a coin in a shallow dish. Look into the dish from a point at which the coin is just out of sight. Pour water slowly into the dish (see Fig. 9-16). Result? Has the coin appeared to move as the water was added?

The changed appearance of the pencil, ruler, black line, and coin shows that light rays are bent when passing from air into water or glass. After water was poured into the shallow dish some of the rays of light from the coin did not pass straight out of the water. They were bent or refracted so as to enter the eye. The ruler was not bent under the water. It only appeared to be bent. Water that is 8 feet deep appears to be only 6 feet deep. A fish under the water seems to be nearer the surface than it really is for the same reason.

The speed of light in air is approximately 186,000 miles per second. But in glass it travels with only *two-thirds*

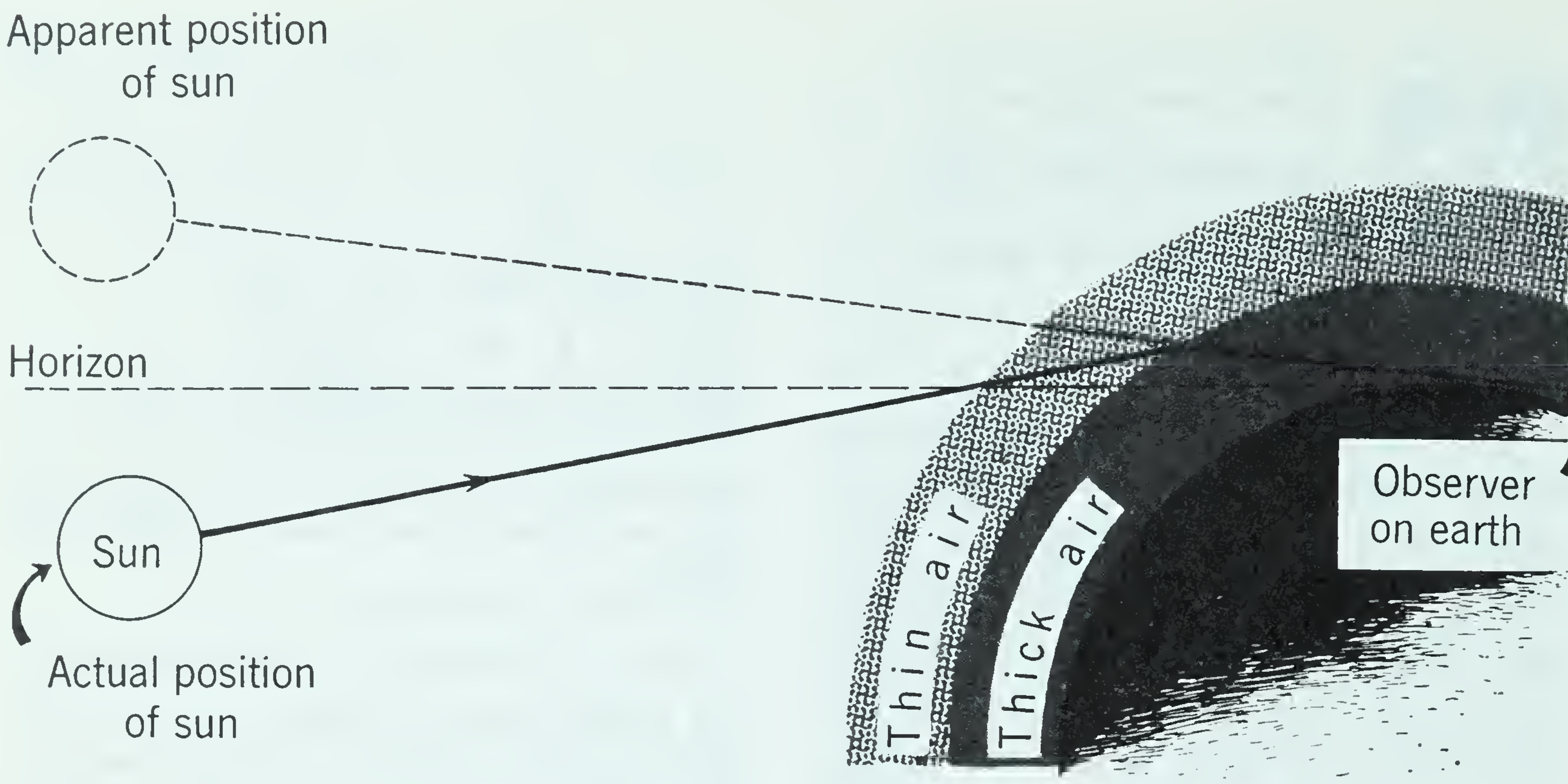


Fig. 9-17. Air refracts light the same way as other substances do.

of this speed. In water it travels at *three-fourths* of this speed. Substances denser than air slow up the rays of light. And when light passes from glass into air, the speed increases. These changes in speed cause refraction. An uneven glass, causing uneven refraction, makes objects appear distorted.

Air can refract light. You can see the sun when it is slightly below the horizon. The rays of sunlight shining obliquely into the thin upper atmosphere are bent toward the ground. This bending continues as the rays of light pass on into the denser air near the earth's surface. (See Fig. 9-17.)

REVIEW QUESTIONS

1. What transparent substances are denser than air? **2.** What is refraction? **3.** Why does the part of a stick under water appear to be bent? **4.** Compare the speed of light in air, water, and glass. **5.** How do you explain the fact that you can see the sun when it is below the horizon?

E How do we use refraction of light?

Convex lenses tend to bring rays of light to a focus. A reading glass or simple microscope is a convex lens. Convex lenses are thickest in the middle. How are convex lenses used to bend rays of light?

DEMONSTRATION

Hold a convex lens perpendicular to rays from the sun or some distant source of light. Put a sheet of paper back of the lens in such a position that all the rays are brought to a point (see Fig. 9-18). Hold the paper in this position for a few minutes. The point where all the parallel rays are brought together is the **principal focus,** or focal point of the lens. The dis-

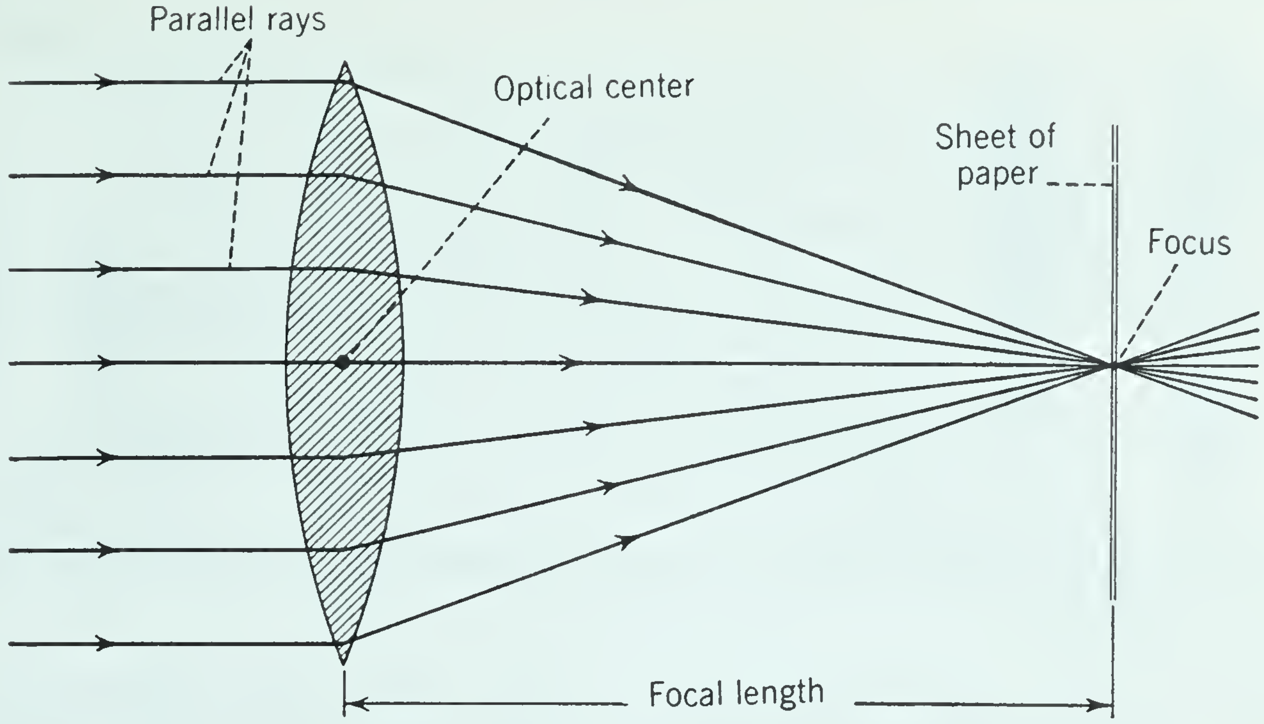


Fig. 9-18. A convex lens brings parallel light rays to a focus. How many instruments can you name that use convex lenses for this purpose?

tance from the center of the lens to the focal point is the focal length of the lens.

An image projected on a screen is a real image. Here is an experiment to show this.

PUPIL ACTIVITY

Put a candle near the lens, but further away than the focal length. Move a sheet of paper back and forth on the opposite side of the lens until a clear image of the candle flame is formed on this paper (see Fig. 9-19). You may have to darken the room to get a clear image. The image of the candle flame may be formed three or four feet away from the lens. Is the image erect or inverted? Move the candle farther away from the lens. Again move the paper back and forth until a distinct image of the candle flame is formed. Does the image become larger or smaller? Brighter or less bright? Remove the paper and put your eye in the same position. Can you see the image of the candle flame? Move your eye back and forth. How does this affect the clearness of the image? Put the candle very close to the lens. Look through the lens at the candle flame. Does it appear to be larger or smaller? Is it erect or inverted?

A convex lens brings parallel rays of light to a focus. Rays from the sun are practically parallel, while many rays of light from a candle are not. They strike the lens from all parts of the candle flame. All rays from each point in the candle flame that strike the lens are focused at a point. All such points together make up the image.

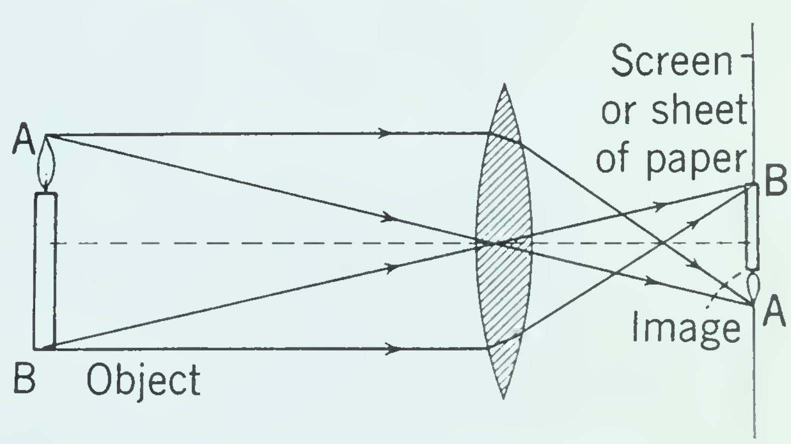


Fig. 9-19. A real image is formed when the object is placed further away from the convex lens than its focal length.

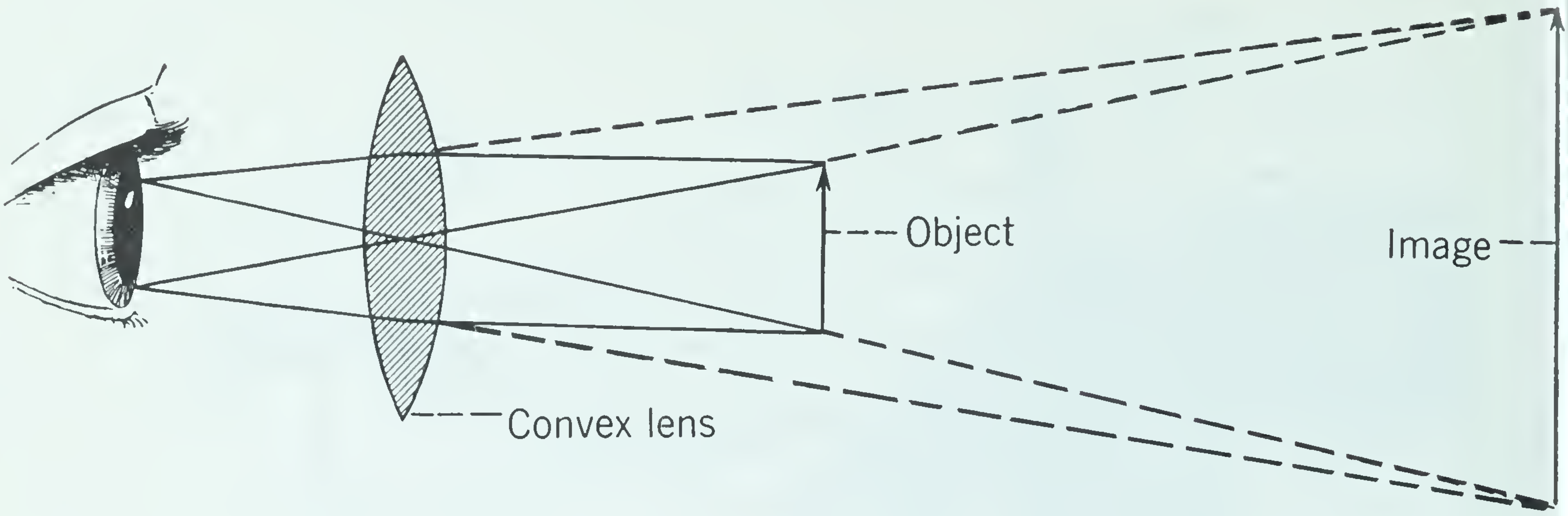


Fig. 9-20. When the object is placed nearer the convex lens than its focal length, the image formed is virtual.

The image is inverted because the rays of light cross each other after they pass through the lens. Fig. 9-19 shows how this happens. A real image cannot be formed if an object is put too near the lens. Under this condition the lens cannot bring the rays of light to a focus. For the same reason, your eye cannot see the print in a book if you put it three or four inches from the eye. The distance of most distinct vision of the normal eye is about 20 feet. For close work the recommended distance is about 15 inches.

Images may be real or virtual. We say images are *real* if they can be projected on a sheet of paper or screen. Real images are always inverted and can be larger or smaller than the object from which they are formed. The size of the image depends on the distance of the object from the lens. *Virtual images* cannot be projected and they always appear to be erect.

A concave lens diverges rays of light. We use a concave lens to spread rays apart and thus give the object a smaller appearance. It is thinnest at the middle. It cannot form a real image, since the rays never come to a focus. If you look through this lens at a candle flame, the image of the flame appears to be small. It is an erect virtual image. Artists use a *reducing glass* to try the effect of reduction of size.

Telescopes form images of distant objects. The type of telescope that uses

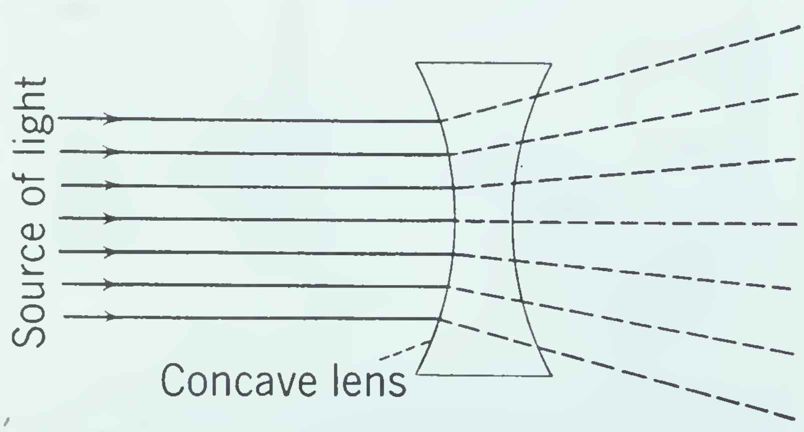


Fig. 9-21. A concave lens spreads out, or diverges, parallel light rays.

Fig. 9-22. A reducing glass is a concave lens.

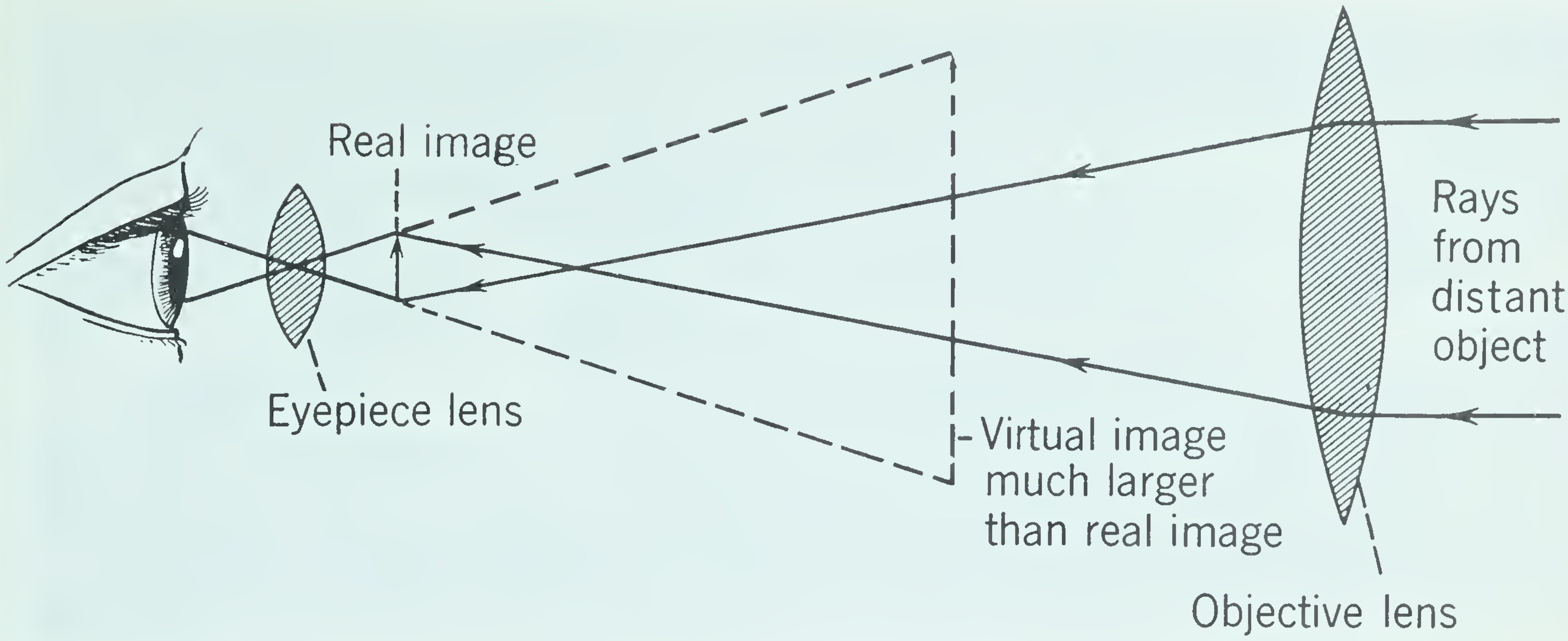


Fig. 9-23. You can make a simple refracting telescope with two convex lenses.

lenses is called a *refracting telescope.* This type is used mostly in smaller instruments, whereas the largest telescopes are of the reflecting type.

PUPIL ACTIVITY

Get two lenses, one more convex than the other. Holding the more convex lens near your eye, move the other lens toward or away from your eye (see Fig. 9-23) until you get a clear image of some object. Is the image erect or inverted? Is it reversed?

This experiment shows the principle of the common telescope.

Microscopes magnify small objects. You can use a single convex lens as a magnifying glass or a simple microscope. To make a compound microscope you will need two thick convex lenses. Fig. 9-24 shows the lens ar-

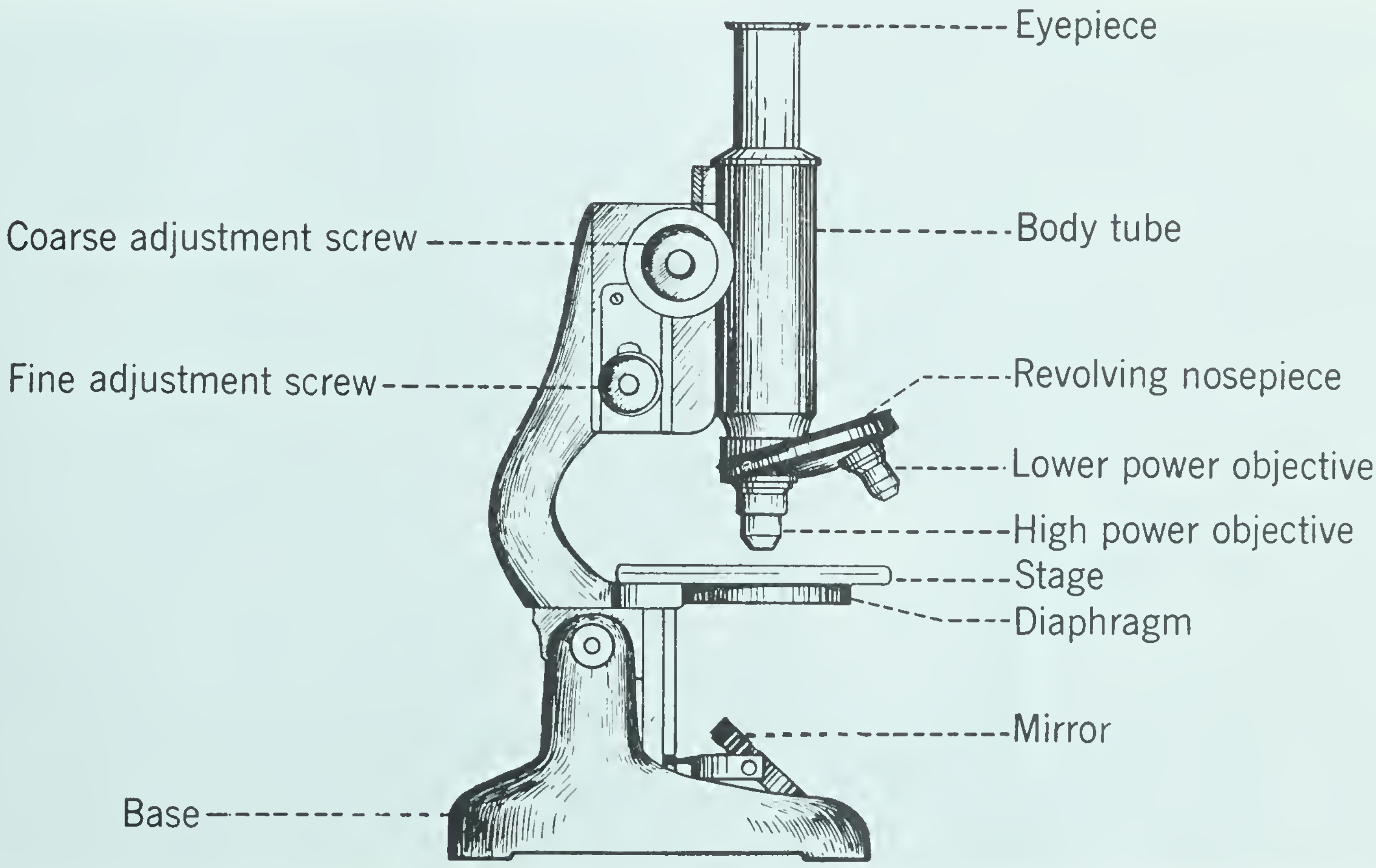


Fig. 9-24. What types of lenses are found in a compound microscope?

rangement in a compound microscope.

Powerful telescopes and compound microscopes work on the same principle. But they have many lenses, grouped in two series.

The compound microscope lets the scientist see the details of structure of very small objects. It is used to see bacteria, to examine the structure of rocks and metals, to study molecular motion, and for many other purposes.

REVIEW QUESTIONS

1. What is a convex lens? **2.** What is a concave lens? **3.** What are real images? Virtual images? **4.** How is a real image formed with a convex lens? A virtual image? **5.** What kind of image is formed with a concave lens? **6.** How are the lenses arranged to make a simple telescope? **7.** What kind of lenses are used to make a compound microscope? **8.** What is a reducing glass? A magnifying glass? **9.** What are some uses of the compound microscope?

F What are the different colors in sunlight?

We can use a prism to separate sunlight into its colors. The paper in this book is white. The print is black. Sunlight is considered to be white light. Black is the absence of color. Do you see the letters, or only the paper around them? What piece of apparatus can you use to show the different colors in sunlight?

DEMONSTRATION

Let a beam of sunlight shine through a prism. Turn the prism until a group of colors appears on the wall or on a white sheet of paper put near the prism. What colors do you see?

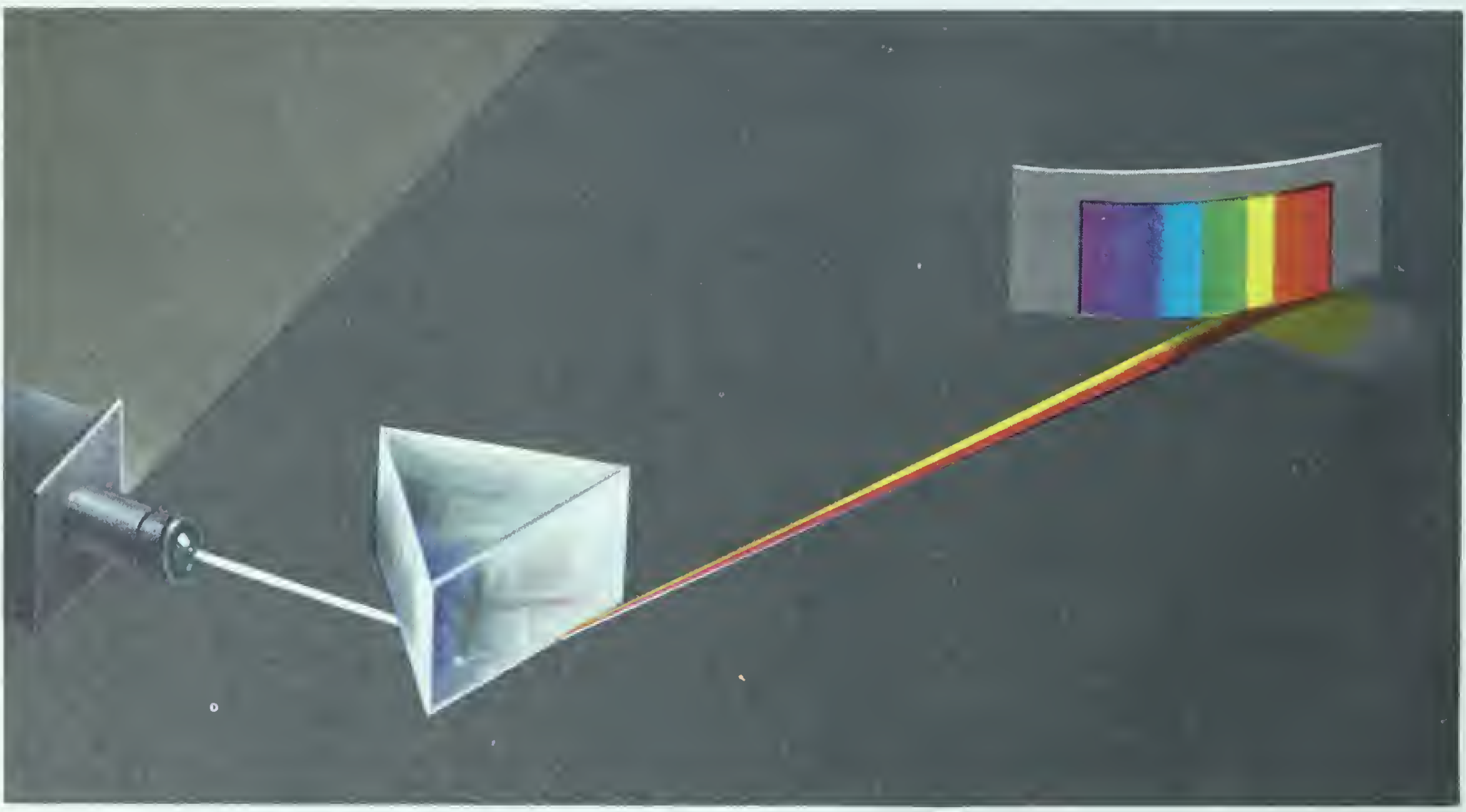


Fig. 9-25. A prism separates white light into its various colors: red, orange, yellow, green, blue, indigo, and violet.

Fig. 9-26. By the use of a second prism colors can be recombined to form white light.

Fig. 9-27. By combining the three primary colors, red, green, and blue, you can produce the other colors, purple, blue-green or peacock-blue, and yellow. How is white light produced? ⟶

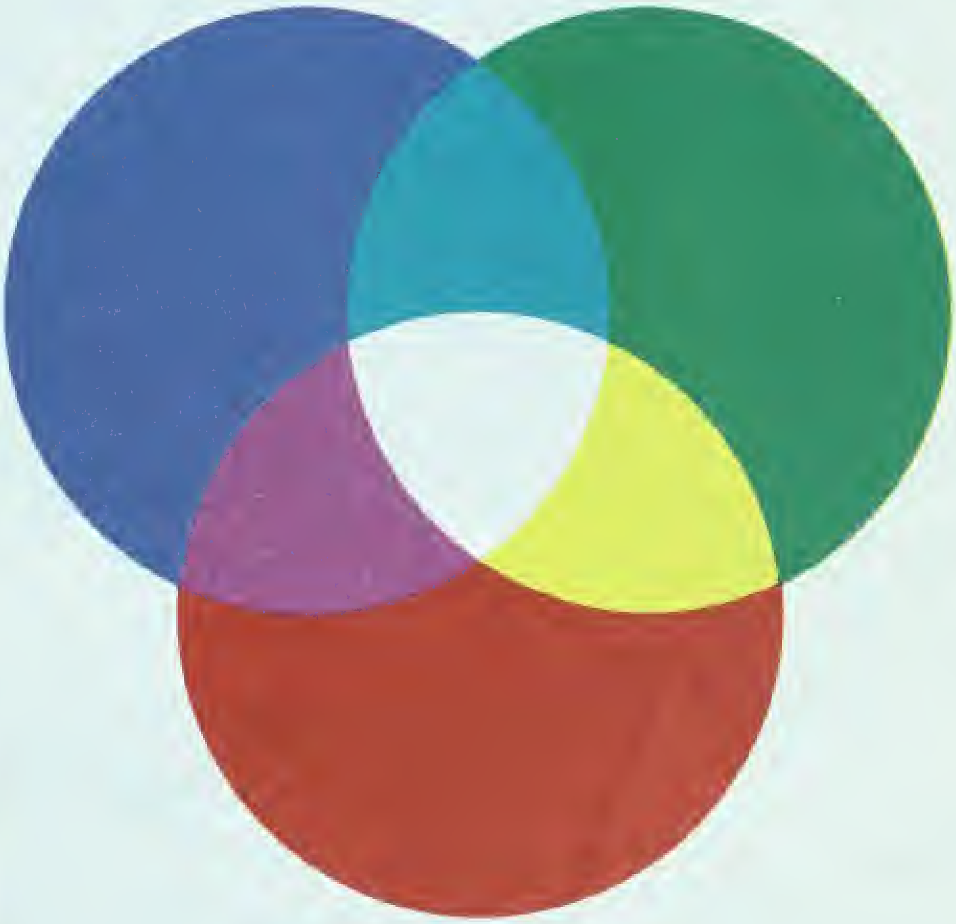


Fig. 9-28. The three primary pigments are crimson-red, yellow, and peacock-blue. Note that when yellow and red pigments are mixed, orange is produced. When blue and red pigments are mixed purple is formed. How would you get black?

Fig. 9-29. The photo on the top was taken with ordinary film. That on the bottom was taken by infrared light on a special sensitive film.

We now have what is known as a sun spectrum. Note that the violet color is bent the most and the red color the least. Also note that the colors merge into each other in this order: red, orange, yellow, green, blue, indigo, and violet. The initials of these words spell the name of an imaginary person, Roy G. Biv. This may help you to remember them in the proper order.

When you put a second prism in the reverse position, as in Fig. 9-26, these colors may be put together again to form white light. Sunlight consists of many colors.

Two or more colors can be mixed to form different colors. If you throw blue and yellow lights on a screen in a dark room, the mixture will appear to be white. Any two combined colors which appear to be white are ***complementary colors.*** You add blueing to clothes which have become yellow to make them white. You can get the same result by putting a sheet of white paper equidistant from blue and yellow light bulbs of the same brightness.

You can get other colors by combining the three ***primary colors.*** These are: *red, green,* and *blue*. In Fig. 9-27, white is produced by the mixture of the three primary colors. *Yellow* is formed by mixing red and green. *Blue-green* results when green and blue are mixed, and *purple* occurs from a mixture of blue and red.

Colored lights produce different mixtures than do the pigments. When true colored lights are mixed, they *add* to each other. But when pigments such as paint, chalk, or crayons are mixed, they will *subtract* from each other.

If you mix yellow and crimson-red paint, you get *orange*. If you make a mark with a peacock-blue crayon on paper and then add yellow on top of it, you get *green*. Crimson-red and blue paint produce *purple*.

The three *primary pigments* are: *crimson-red, yellow,* and *peacock-blue,* as shown in Fig. 9-28. But look again at Fig. 9-27. The three primary pigments are the complements of the three primary light colors! A mixture of the three primary pigments appears to be black. This combination absorbs all colors and none is reflected.

Light waves in different colors have different rates of vibrations. Some light waves are bent more than others by the prism, with the result that they are sorted out. Rainbows are formed on the same principle by the sun's rays striking drops of rain and being refracted by the water. The resulting spectrum is reflected to an observer's eye. During what part of the day can you see rainbows? Have you noticed the same effect when the sun is shining on a fine spray of water, or when you let sunlight pass through a glass of water? To see this effect, should you face the sunlight or should you look away from it?

The color of an opaque object is the color it reflects. A white object *reflects* all the different wave lengths of light that fall on it. A black object *absorbs* all the different wave lengths of light that fall on it (see Fig. 9-30). An object is red because more red light is reflected to the eye than any other color. Most of the other colors are ab-

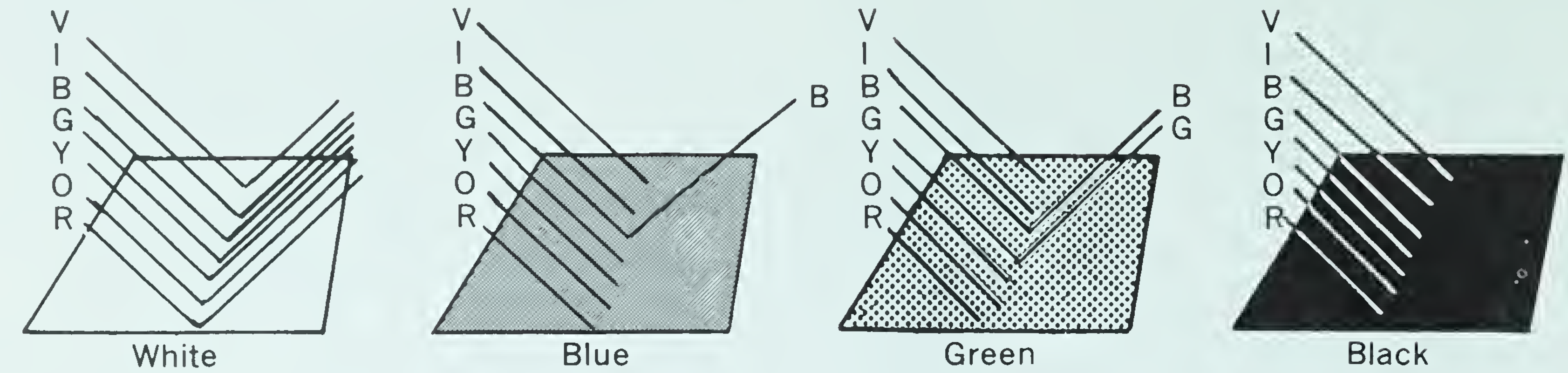


Fig. 9-30. The color of an opaque object, like cloth, is the color which it reflects. As you can see in this diagram, the other colors in the spectrum are absorbed.

sorbed. An object appears to be green because green light is reflected to the eye.

REVIEW QUESTIONS

1. What makes objects have color? **2.** What is white light? **3.** What does black mean? **4.** What are the seven elementary colors of the rainbow? **5.** How are rainbows formed? **6.** Why do some objects appear to be red, while others seem to be white? **7.** How is the mixing of lights different from the mixing of pigments?

G How does a camera take a picture?

The pinhole camera exposes the film by letting light enter a small opening. This type of camera will give good results under certain conditions.

PUPIL ACTIVITY

Get a box about the size of a small shoe box as in Fig. 9-31. Remove one end and then cut an opening about two inches square through the opposite end and cover it with tin foil. Make a pinhole through the center of the foil. Blacken the inside of the box with ink or paint. Make a sliding screen out of waxed paper on a frame that will just slide into the end of the box opposite the tin foil. Darken the room and put a lighted candle in front of the pinhole. Can you see its *image* on the waxed paper screen? Move the screen back and forth to see if you can see the image more plainly. Is the image erect, or inverted?

Point the pinhole camera toward a well-lighted object. Result? Make a drawing to illustrate how the image is formed. Explain why the image is inverted.

In a pinhole camera there is no simple way to control the length of time the light enters the camera. The image will be clear but the brightness varies as the distance of the object from the camera changes. In pinhole cameras you cannot move the film back and forth, so the size of the image changes with the distance of the object from the opening.

A lens camera is more efficient than a pinhole camera. Examine a real camera. Note that there is a lens in place of a pinhole. A *shutter* controls the length of time the light enters the

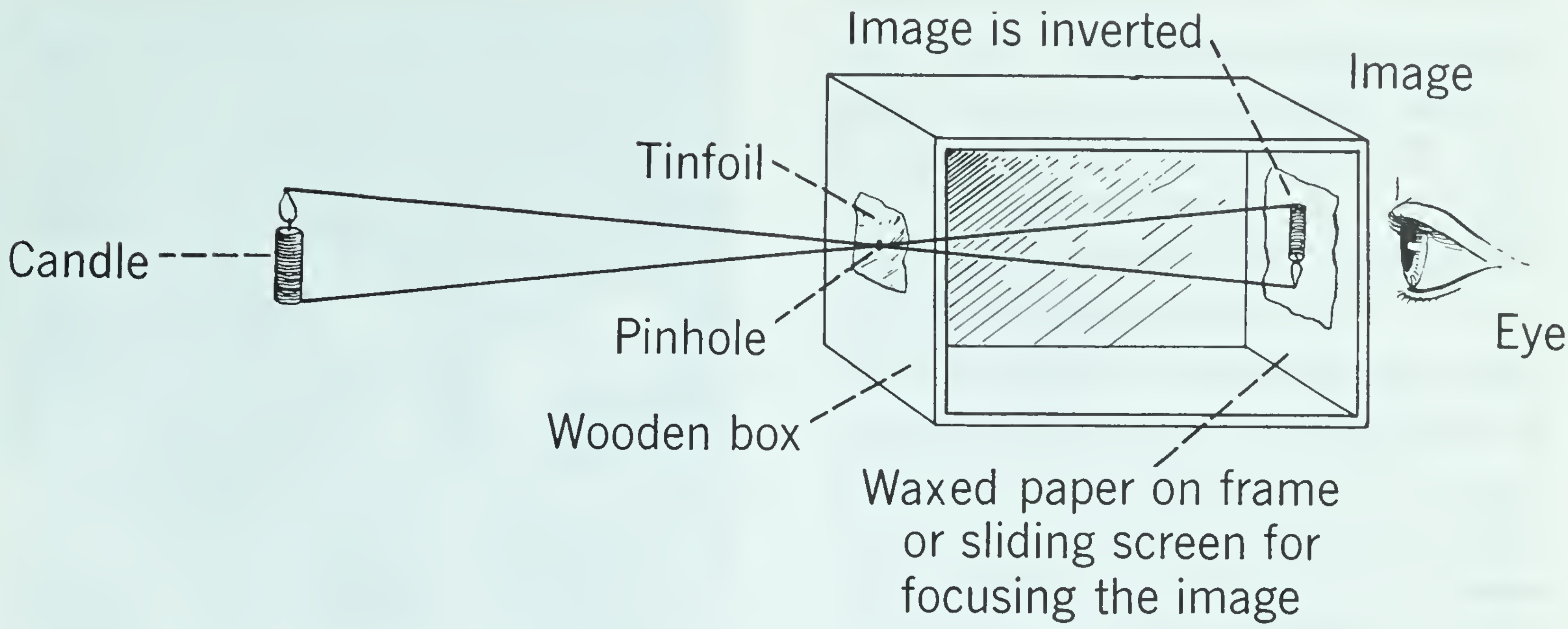


Fig. 9-31. In a pinhole camera, the size of the image changes with the distance of the object from the opening.

camera. You can open it for only a fraction of a second or for longer. The *lens* allows a large amount of light to enter the camera because the opening is larger. The lens may be moved back and forth to get a distinct image of the object to be photographed. By controlling the amount of light entering the camera and by getting distinct images, it is possible to get good pictures each time.

The image in a camera is focused on a sensitive *film*, or *plate*, which is exposed to light only when the shutter is opened. When this exposed film or plate is treated with certain chemicals (developed and fixed), a *negative*, or reversed picture, appears on it. The

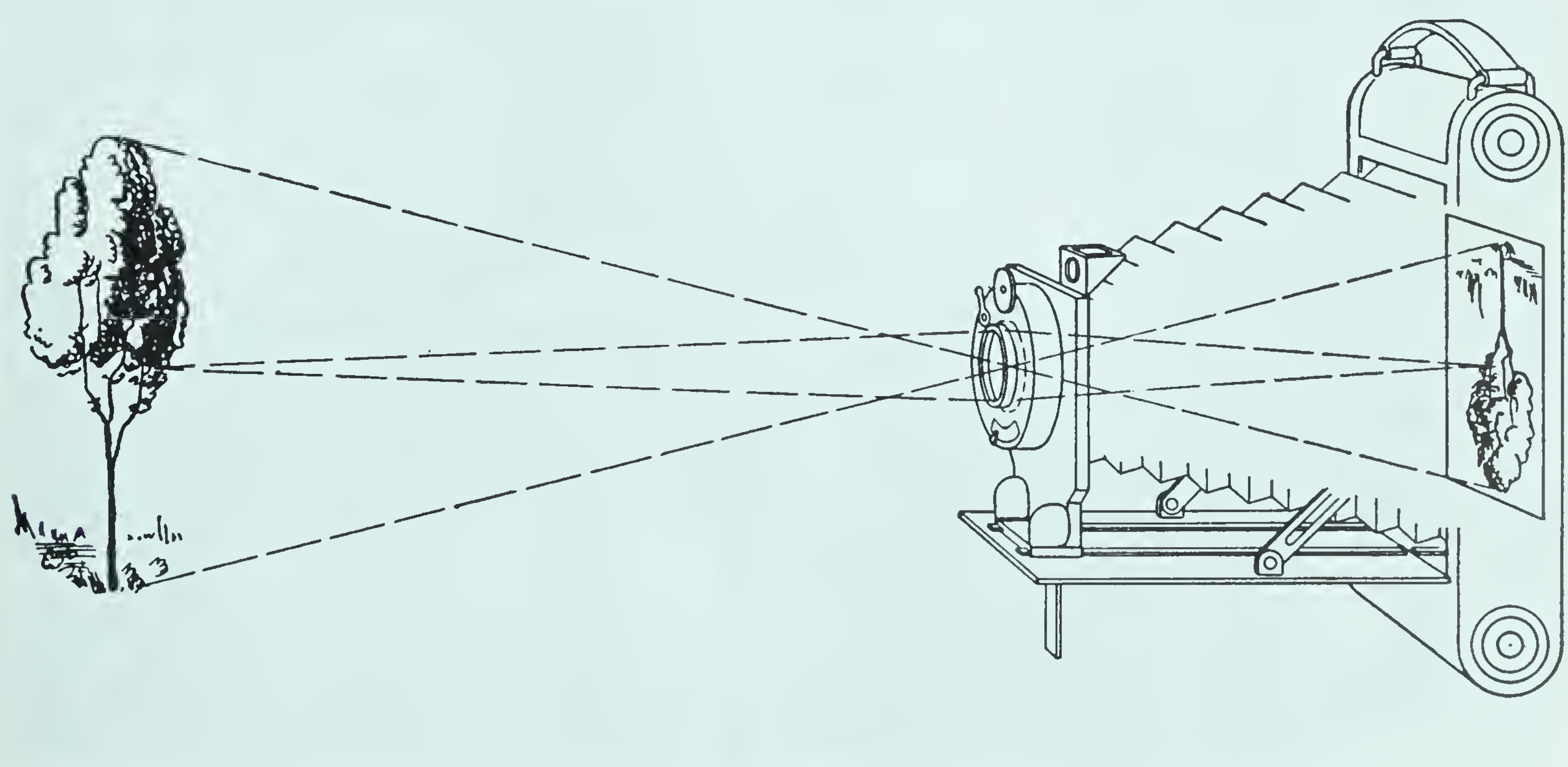


Fig. 9-32. In a lens camera, you can control the length of time light enters the camera. Why is this an advantage over the pinhole camera?

real picture, or *positive*, is printed from the developed negative.

Color photography is now widely used. The same camera that takes ordinary pictures can be used in color photography. However, special film is required. This film consists of layers which are sensitive to different colors in white light. It must be developed by a special process. The lower photograph in Fig. 9-29 was taken on film sensitive to invisible infrared light, which is beyond the red end of the spectrum.

Fig. 9-34. A photoflash attachment on your camera gives you the necessary illumination for taking pictures anywhere, anytime.

REVIEW QUESTIONS

1. What is the main difference between a pinhole camera and a lens camera? **2.** Which is more efficient, and why? **3.** What is the difference between a negative and a positive picture? **4.** Name the essential parts of a camera and describe the function of each part.

Fig. 9-33. A positive print (right) on specially coated paper is made from the photographic negative or film (left).

H How do the eyes see things?

The lens in the eye is a convex lens. Now that we have some idea of light and how it can be handled by a camera, we can understand the eye. The human eye resembles a camera in its main features.

Observe the eye as shown in the diagram in Fig. 9-35. The outer, transparent, protective covering is the *cornea* (*kor*-nee-ah). The next part is the *iris,* or colored curtain. This acts like a diaphragm or shutter in controlling the amount of light entering the eye. The ***pupil*** is the round opening through the iris, like the lens opening of a camera. The *lens* itself is convex and lies just behind the pupil opening of the iris. The inner layer of the eye is the *retina* (*reh*-tin-ah), corresponding to the sensitive film of a camera.

The space between the cornea and the lens is filled with a watery liquid, the *aqueous* (*ay*-kwee-us) *humor.* The remaining space in the eyeball contains a thicker liquid, the *vitreous* (*vit*-ree-us) *humor.* Both are transparent and help to give the eyeball its shape.

The *optic nerve* that carries sight messages to the brain enters the back of the eye. Its millions of tiny endings of nerves spread out to all parts of the retina.

PUPIL ACTIVITY

Stand near a mirror. Look at a bright light for a minute. Now quickly look in the mirror and note the size of your pupil. Then close your eyes for a moment. Again look quickly in the mirror. Why has the pupil changed in size?

Small muscles in the iris control the size of the pupil. How does the iris correspond to the diaphragm of a camera? Why is this adjustment necessary?

The lens changes shape for focusing. You can move the lens of your camera backward or forward to focus the image on the film. But we have no such arrangement in the eye. How then can the image be focused?

PUPIL ACTIVITY

Look at a word on this page. Now look at some small object in the distance. Quickly look at the word again. Result?

Evidently some change takes place in the eye before you can clearly see a near object after having looked at a distant object, and vice versa. This is called *accommodation of the lens.* What takes place? Note in Fig. 9-36 that when light from a distant object passes into the eye, the lens is thinner than when light enters from a near one.

The lens is elastic and is thickened by the pull of certain muscles. When you observe near objects, these muscles contract and the lens becomes thickened. When you look at distant objects, these muscles relax and the lens becomes thinner. This is why looking off into space is a good way to relax the eyes when they are tired from too much close work. So we see that in-

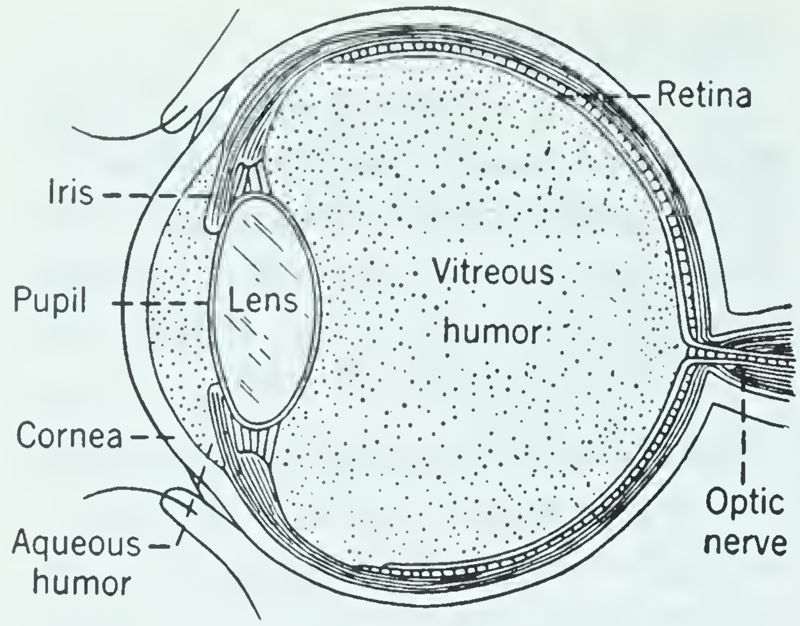


Fig. 9-35. What are the functions of each part of the eye? Compare the eye and its parts to a camera and its parts.

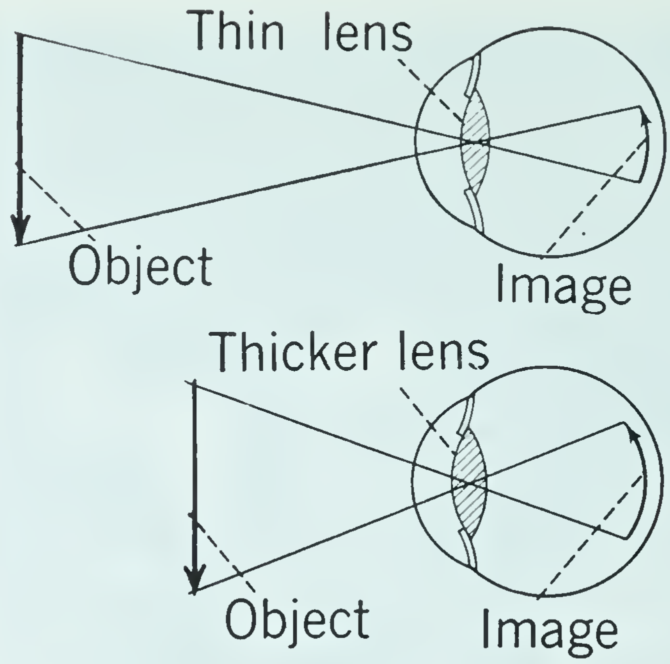


Fig. 9-36. The eye focuses objects at different distances by changing the curvature of the lens.

stead of changing the distance of the lens from the retina, the same purpose is accomplished by changing the shape of the lens.

Some light effects deceive the eye. Is seeing believing? Look at the diagrams in Fig. 9-37. Which set of parallel lines seems to be higher, D or E? Which look broader? Should stout people wear clothing with horizontal stripes? Study the two vertical lines B and C. Which is longer? Now measure them. Why does the man on the left in A seem taller than the others?

Eyes may be defective. There are many forms of imperfect vision, of which nearsightedness and farsightedness are by far the most common defects.

In *nearsightedness*, the light rays come to a focus in front of the retina and distant objects are not clear. *Concave lenses* in glasses will correct this (see Fig. 9-38).

In *farsightedness*, the rays come to a focus back of the retina. The image on the retina is not clear. Here *convex lenses* are used to help the eye to get a clear image on the retina.

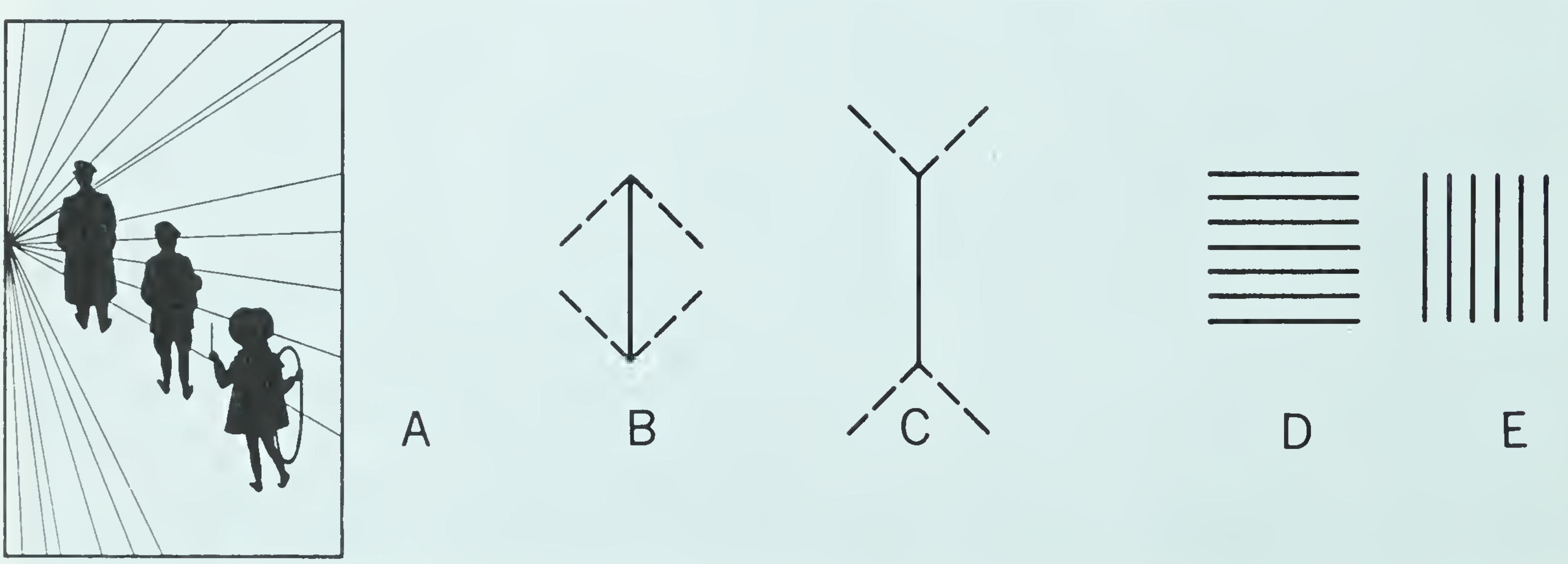


Fig. 9-37. Some things are not always what they seem at first. As you see here, some light effects are quite deceptive.

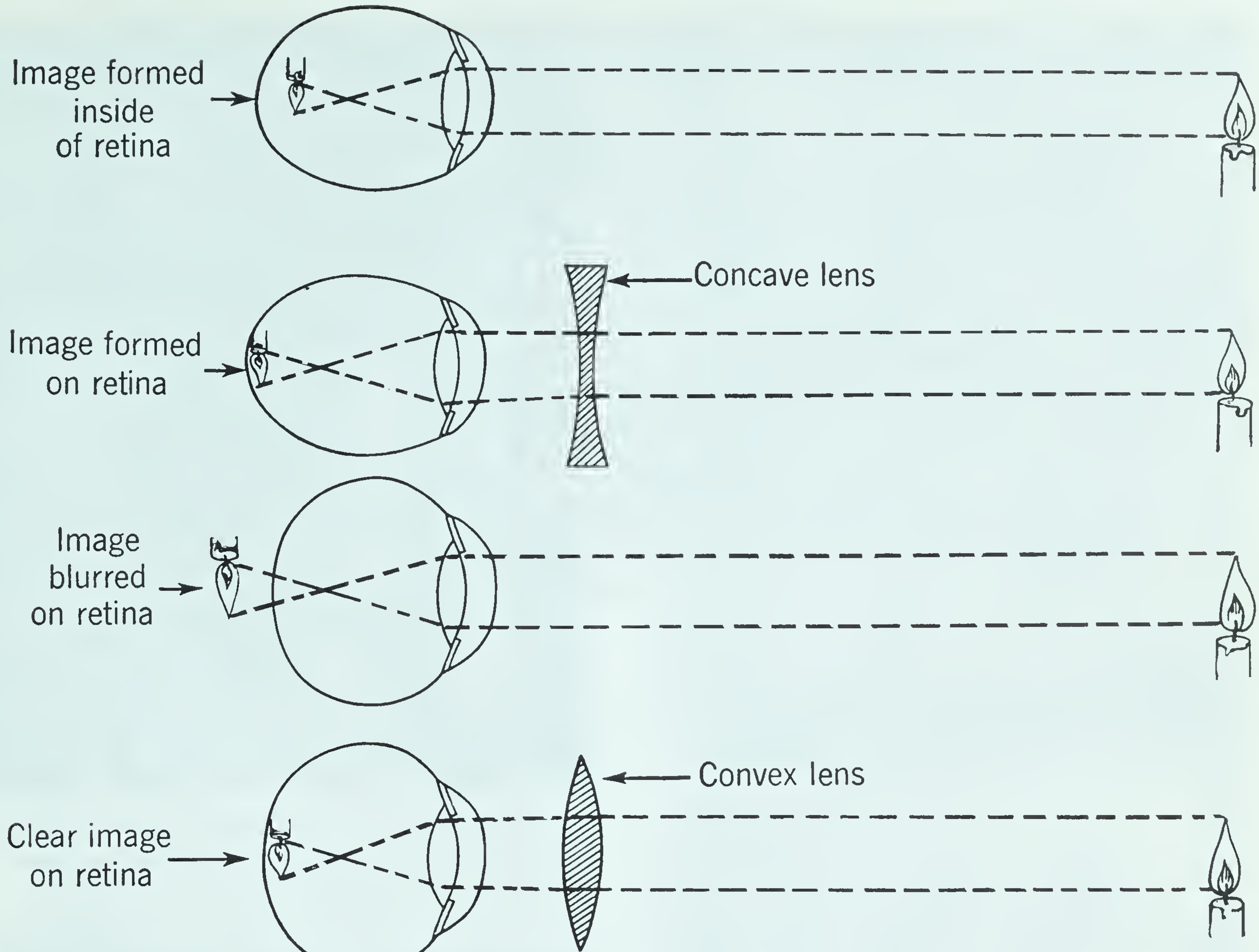


Fig. 9-38. The diagrams show how lenses can correct eye defects such as nearsightedness (top) and farsightedness (bottom).

Movies do not move on the screen. Watch the rapidly revolving spokes of a wheel. Can you see each spoke? Revolve a color disk of the seven sunlight or elementary colors. Can you see each color?

Evidently it takes time to form pictures on the retina. It also takes time for them to be replaced by other pictures. Now, as the spokes of the wheel are rapidly revolving, no single spoke is pictured distinctly before it moves on. A blurred image is formed of many spokes. When the colored disk is whirled, the colors all combine into a grayish-white color. This is proof, incidentally, that white light is composed of the combination of the seven elementary colors. It also shows that picture impressions overlap on the retina.

Movies depend on the same effect. Before the impression from a certain picture cast upon the screen is removed, another slightly different one is blended with it. This gives us the effect of a single picture in motion.

The image of an object on the retina persists from $\frac{1}{20}$ to $\frac{1}{16}$ of a second after the object causing the image is removed. When a film is made, 24 exposures or frames are taken each second. When these pictures are projected on a screen, they follow each other at about the same rate. This gives the ef-

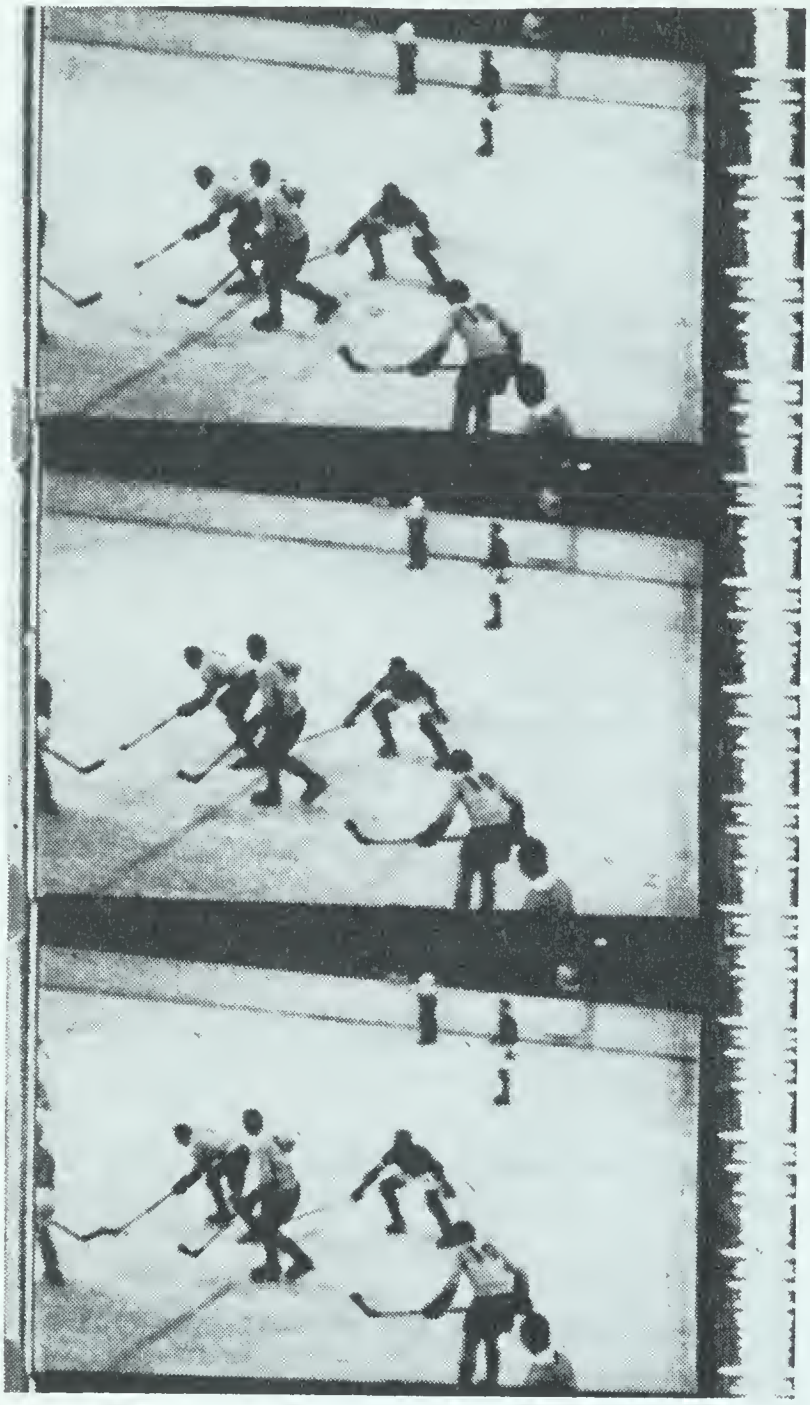


Fig. 9-39. Each frame on a motion picture film is slightly different. When these pictures are projected rapidly on a screen, one gets the effect of motion.

Fig. 9-40. This is a single frame from a motion picture which was filmed by the CinemaScope process.

fect of continuous motion due to the persistence of vision. Each picture on a film is slightly different from the one before. These small changes are projected rapidly and you see a series of still pictures which are shown quickly enough so that you seem to see a picture in continuous motion.

A revolving shutter within the projector blocks off the light from the projection lamp during the instant when the machine changes from one still picture to the next. This helps to

Fig. 9-41. The pair of photoflood lamps gives the extra-bright illumination needed for taking home motion pictures indoors.

Fig. 9-42. This is the same frame as in Fig. 9-40 after it has been projected through a special lens on a theater screen.

avoid the annoying flicker of the old-time movie projectors. If your school owns a motion picture projector, you may be able to study its operation. In this way you will get a better understanding of how motion pictures are projected.

The pictures on the films are positive prints. Light from a strong source is passed through the film, and by using a series of lenses, an enlarged image is thrown on the screen.

In Cinerama the illusion of depth is achieved by using three synchronized motion picture projectors. The images are formed on a very wide curved screen. CinemaScope also uses a wide-angle curved screen. A special lens in the projector spreads the image out to fill the screen. See Figs. 9-40 and 9-42.

REVIEW QUESTIONS

1. How does the eye resemble a camera?
2. Explain the causes of some defects of the eye and how they can be corrected.
3. Why does a moving picture on the screen actually not move?

I How is the modern home lighted?

An electric discharge will heat gases until they glow. When a lightning flash passes through the air, it is not electric energy that you see. It is air heated by the electric spark to a brilliant glow. Such glowing of substances caused by intense heat is called *incandescence* (in-kan-*deh*-sense).

Neon lights are filled with neon gas. When an electric discharge is passed through this gas, the characteristic red color is formed. Other gases are used to produce different colors. Mercury gives off blue light when it is vaporized and an electric discharge is passed through it. This light is easy on your eyes but not satisfactory for selecting colors.

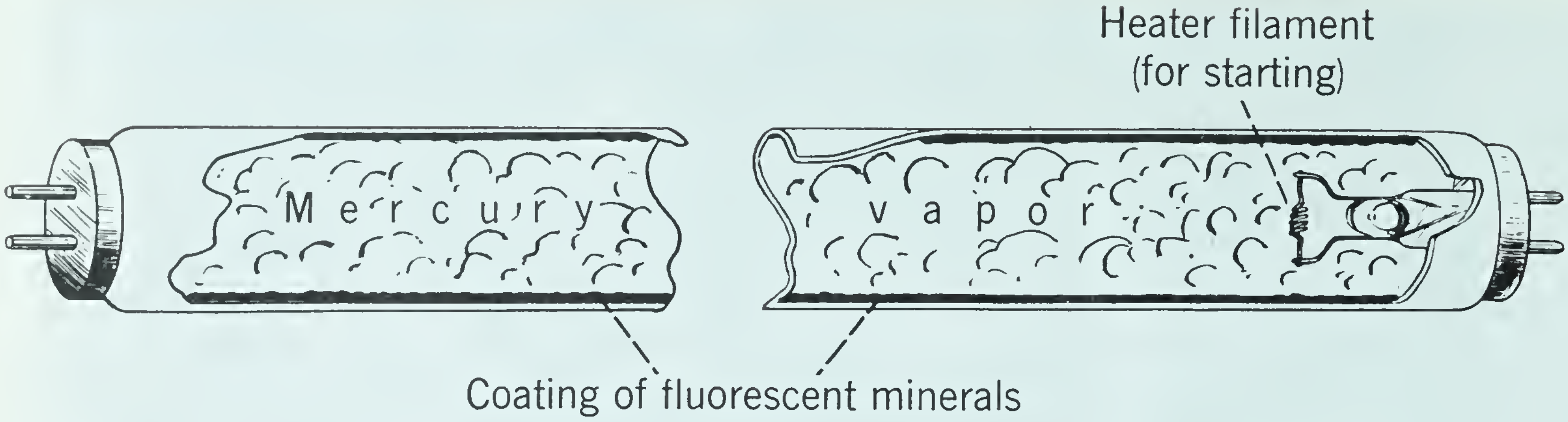


Fig. 9-43. This cutaway of a fluorescent lamp shows its structure. Explain how it operates.

Filaments give off light when heated. If an electric current passes through the wire filament in a light bulb, the filament is heated enough to give off light. The filament is made of *tungsten* which can be heated to high temperatures without melting. It is necessary to remove air from inside the bulb to prevent the filament from oxidizing or burning. Then other gases which do not act on the filament are put into the bulb. This is an *incandescent lamp.*

Another common lighting device is the tubular fluorescent lamp. In this one, the light is produced by minerals which glow when exposed to invisible ultraviolet light. The ultraviolet light is the result of passing a high voltage electric current through a small amount of mercury vapor.

Fluorescent (flew-or-*eh*-sent) lamps give light that is more nearly like daylight than the light from incandescent lamps. They are cooler in operation and cheaper to run. This economy of operation is important where artificial light is used for long periods of time. The one big drawback to the wider use of fluorescent lamps is their cost of installation.

We measure the brightness of light in candle power. One *candle power* is the brightness of light given by one standard candle. The brightness of a 25-watt tungsten lamp is about 20 candle power, that of a 100-watt lamp with inside frosting is about 80 candle

Fig. 9-44. A light meter measures the intensity of light in foot candles.

power. The light intensity at any point one foot from a standard candle is called a *foot candle.*

The intensity of light decreases with the distance from its source. It is important to arrange lights so their intensity will give enough light for reading, sewing, and other work.

DEMONSTRATION

In a dark room, put a candle or electric flashlight one foot from a cardboard which has a hole one inch square at the center (see Fig. 9-45). Let the light enter the hole in the first cardboard and strike a second cardboard. Mark this off in square inches and hold it two feet from the candle. How many square inches does the beam of light cover on the second cardboard? Move the second cardboard three feet from the candle. How many square inches are covered by the beam of light?

From this demonstration you have learned that a beam of light one inch square in cross-section, at a distance of one foot from the source of light, spreads until it becomes 4 square inches at a distance of 2 feet. It becomes 9 square inches at a distance of 3 feet from the source. If the same light spreads over more space, the intensity of the illumination must be less.

There are three common methods of lighting houses. These are: (1) *direct lighting;* (2) *indirect lighting;* and (3) *semi-indirect lighting.* When lighting a room, we must bear in mind that strong direct light should be avoided. Certain places must be better lighted than others.

In using ***direct lighting,*** the light is thrown directly on the object to be lighted by a reflector or directly from the lamp. This may produce a glare that is injurious to eyes. If, in reading, you put your book so the light from the lamp is reflected directly from the book to your eyes, you will soon notice that your eyes tire. There is less loss by absorption in the direct lighting method, and a greater intensity is produced.

Light is reflected from the ceiling and walls in the ***indirect method*** of

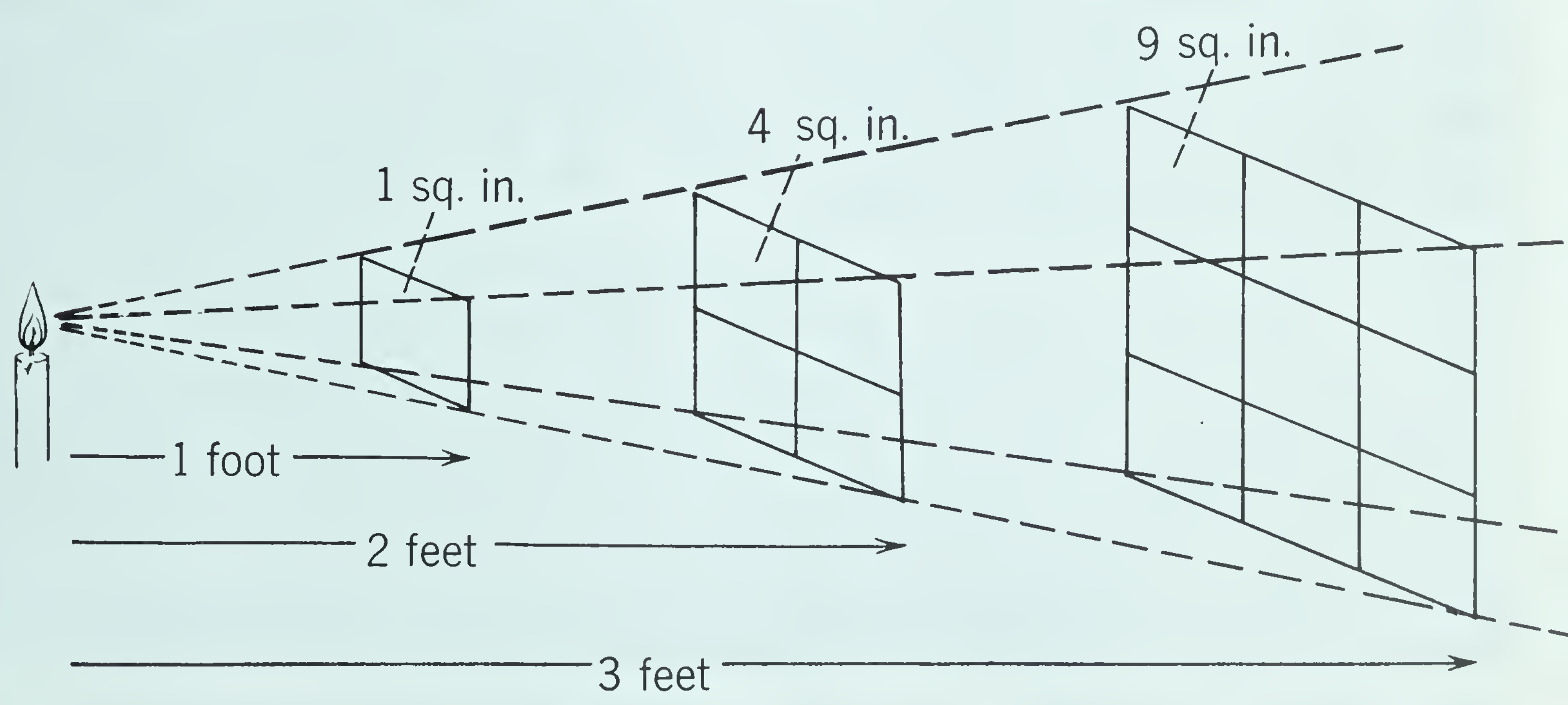


Fig. 9-45. The intensity of light decreases as the square of the distance from its source increases.

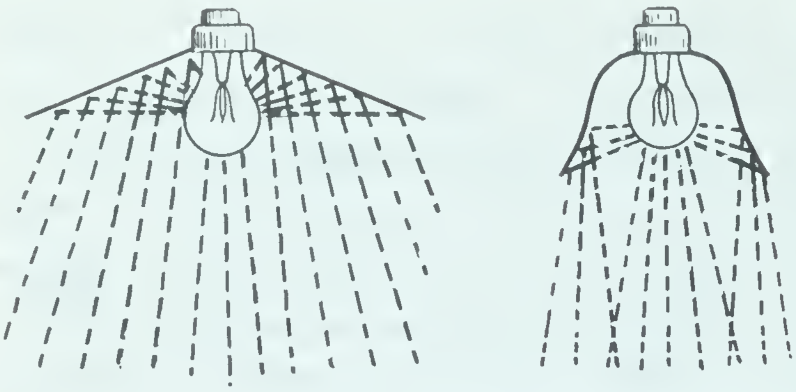
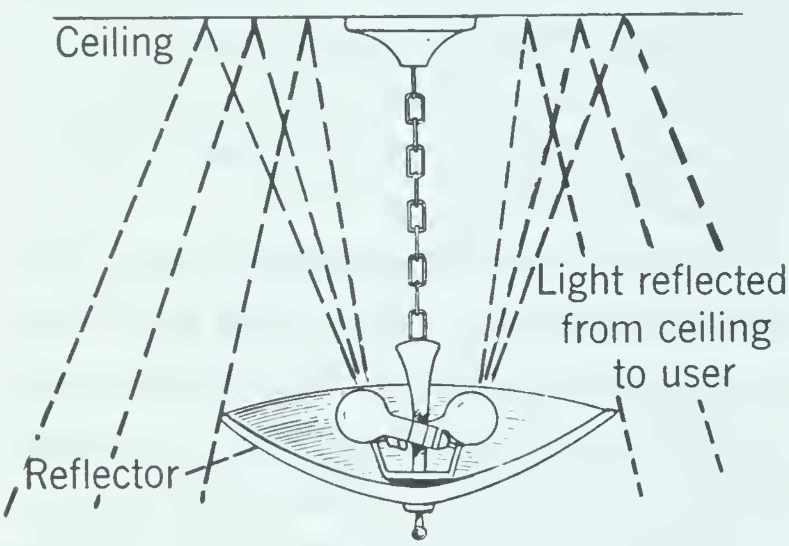


Fig. 9-46. In direct lighting, the light is thrown directly on the object by a reflector or directly from the lamp.



Indirect lighting

Fig. 9-47. Indirect lighting gives diffused light. However, it is not very efficient because much of the light is absorbed.

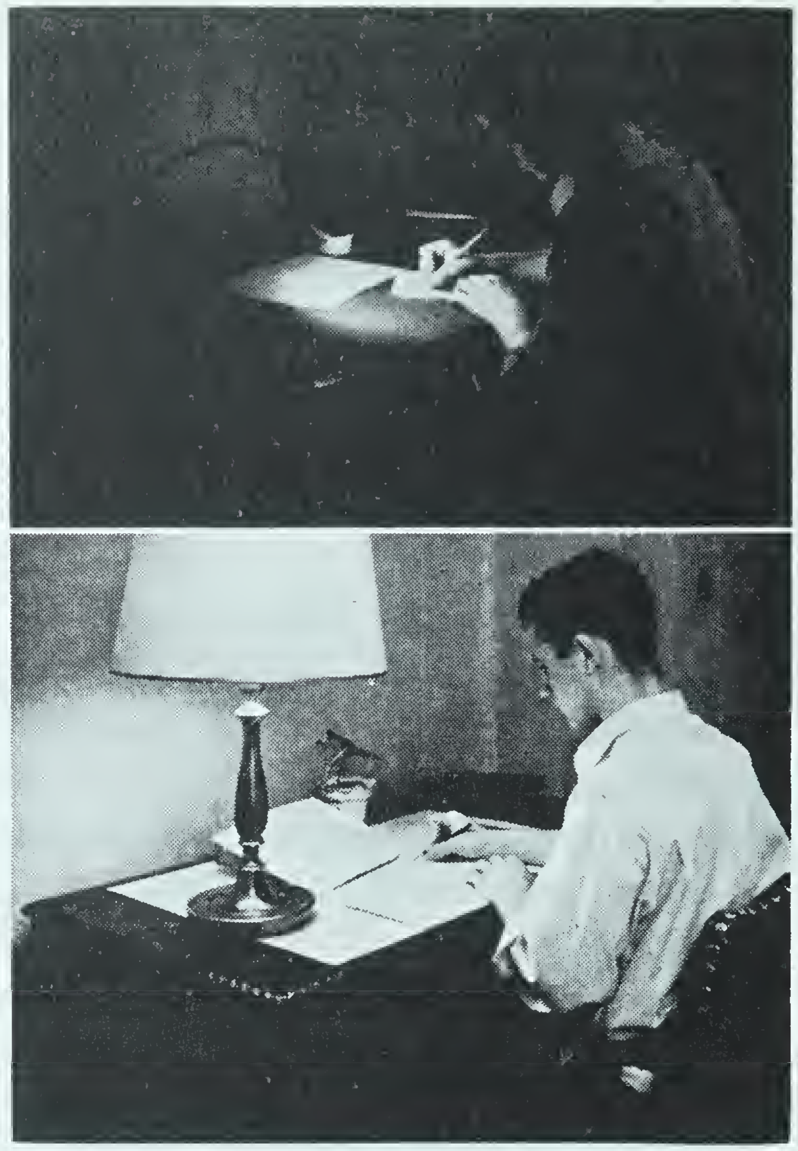


Fig. 9-48. The poor lighting in the picture on the top makes it hard for this boy to study properly. The improved lighting in the picture on the bottom means less strain on the boy's eyes and greater efficiency.

lighting. Indirect lighting is the ideal but expensive method because much of the light is absorbed. It is produced by putting an opaque reflector between the eyes and the lamp, thus directing light up against the ceiling. It is reflected from the rough ceiling and walls to all parts of the room. This supplies *diffused light* for the room. In the *semi-indirect method* the reflector is made of translucent material. Most of the light is reflected to the ceiling, but some of it passes through the reflector. This method removes glare and is quite satisfactory. In the indirect method of lighting the walls should be light-colored to prevent absorption of light, and rough enough to diffuse light.

Many rooms are poorly lighted because the sources of light are not well placed. Lights near the ceiling or on the ceiling reflect or diffuse little light to the lower part of the room. Lights on the upper part of a side wall give little light on the opposite side of the room. In indirect lighting, the light is well distributed in the room. However, much of this light is absorbed by upper parts of the walls.

Then, too, many rooms have dark-colored walls. These walls absorb much light. Dark walls absorb more light than white walls. To be well-

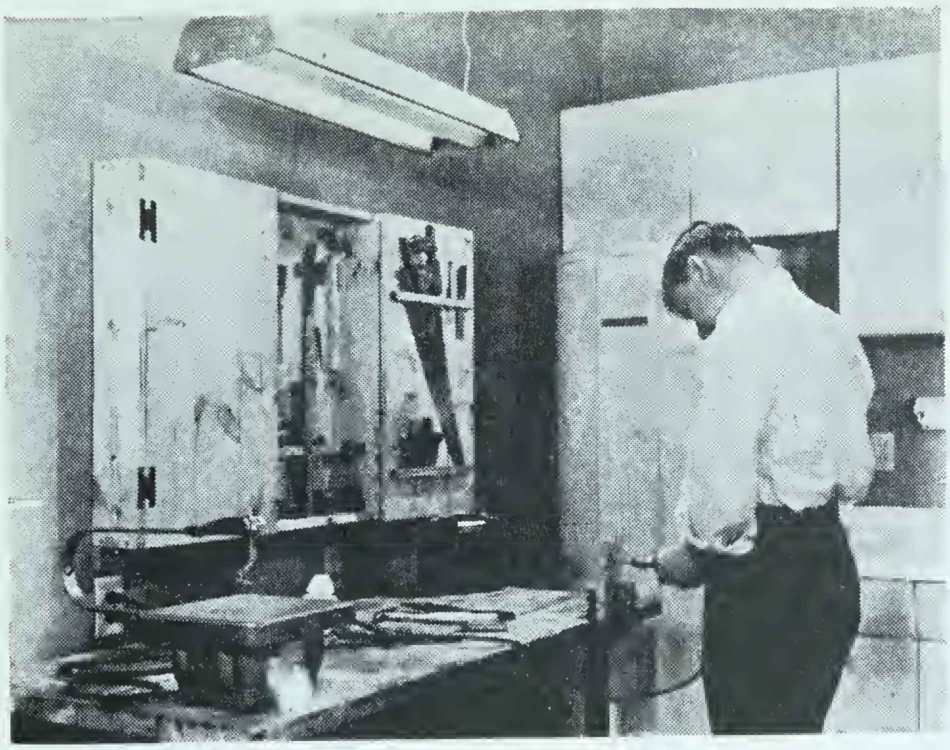


Fig. 9-49. Proper lighting is essential to the safe use of tools. As shown in this photograph, a plug-in fluorescent unit can be used to provide ample light on the working surface of the bench.

lighted, a room should have light-colored walls and enough lights well distributed to illuminate all parts of the room.

REVIEW QUESTIONS

1. In what ways can artificial light be produced? **2.** What are the advantages and disadvantages of each kind? Consider cost, safety, cleanliness, and amount of light produced. **3.** What is candle power? A foot candle? **4.** What are the advantages and disadvantages of the three different methods of distributing light? **5.** Explain why illumination in a room is improved by using light colored paint on the upper walls and ceiling.

Fig. 9-50. Good lighting on highways is as important as good lighting in the home. Many accidents have been prevented by modern highway lighting.

QUESTIONS FOR REVIEW AND DISCUSSION

1. How does light come to the earth from the sun?
2. How are radiant waves changed to noticeable heat? What practical applications are made of this change?
3. Why are frosts less likely to occur on cloudy nights?
4. Why are cloudy days usually not so warm as those days on which the sun shines brightly?
5. What principle of light do we recognize when we aim a rifle?
6. What is a shadow? What are the parts of a shadow?
7. How does light enter a window on the north side of a house in winter?
8. What kinds of surfaces make good reflectors?
9. What kinds of surfaces are used to diffuse light?
10. What are the differences between real and virtual images?
11. Under what conditions is an eclipse of the moon produced? Eclipse of the sun?
12. How is light refracted?
13. If you were shooting obliquely at an object under water, where would you aim to hit it?
14. What causes a rainbow?
15. What is white light? What does black mean?
16. Why are the walls of courtyards and air shafts painted white?
17. Why is the inside of a camera black?
18. What are the parts of a camera? What is the purpose of each?
19. Compare the human eye and the camera. In what ways are they alike? In what ways are they different?
20. Why is white clothing preferred for summer?
21. What is a convex lens? A concave lens?
22. Under what conditions does a convex lens form a real image? A virtual image?
23. What makes objects have color?
24. How is nearsightedness corrected?
25. How is farsightedness corrected?
26. What makes movies appear to move?
27. What methods are used to produce light in the home?
28. What three methods are used to distribute light in a house? What are the advantages and disadvantages of each?

29. How is the intensity of light affected by increasing the distance from the source?
30. How do they make slow motion pictures?
31. What are the three primary colors? How are they mixed to produce white? Green? Purple?
32. What are the three primary pigments? What combination of pigments is needed to produce black?
33. What gives an opaque object its color?
34. What are the seven elementary colors in the sun's spectrum as formed by a prism?
35. What different kinds of radiant energy are given off by the sun?
36. What are the advantages of a fluorescent lamp over the tungsten lamp? What are its disadvantages?
37. Why do they darken the insides of telescopes and microscopes?
38. How are ordinary black and white photographs produced?
39. How is color photography different from black and white?
40. How is a magnifying glass different from a reducing glass? Describe uses for each.
41. How are motion pictures in Cinerama and CinemaScope produced?

SPECIAL REPORTS AND PROBLEMS

1. Make a simple telescope.
2. Demonstrate the action of a motion picture machine.
3. Demonstrate the action of a stereoscope.
4. Make and demonstrate a model of a compound microscope.
5. Take some pictures of the class. Develop and print the pictures.
6. Demonstrate how a flashlight works.
7. Demonstrate how automobile headlights can prevent glare.
8. What lighting system is used in your home? How is the light distributed?
9. Demonstrate how you use a light meter.
10. Make a report on color blindness and how this condition is detected.
11. Prepare a slide and demonstrate how a microscope forms a large image of a small object.
12. Use colored crayons or water colors to demonstrate the effect produced by mixing two or more pigments.
13. Consult a book on interior decoration and find out which colors make the most pleasing combinations for walls, draperies, and slip covers.
14. Report on the history of making successful moving pictures.
15. Report on the various types of telescopes.
16. Report on the history of the microscope.
17. Report on the uses of time lapse photography.
18. Report on how color film is developed and printed.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: incandescence, opaque, translucent, transparent, shadow, incident rays, umbra, penumbra, real image, virtual image, reflection, diffusion, light, focus, sun spectrum, luminous, pigment, complementary colors, nearsightedness, farsightedness, candle power, foot candle, direct lighting, indirect lighting, reflected rays?
2. What part do the following have in your daily activities: mirror, lens, prism?
3. How have the following benefited man: the microscope, the telescope?
4. Under what conditions is it correct to say one method of illumination is better than another?
5. Artificial methods of lighting are inefficient. In what ways do you think their efficiency could be increased?
6. Why was the discovery of glass important? What instruments or apparatus have been developed as a result of this discovery?
7. What is the shortest length mirror that can be used to see your entire length?
8. Why do the images of trees on the opposite side of a still body of water appear to be inverted? Hold a lighted candle above a jar of water but on the opposite side from where you stand. Observe the candle flame in the water.
9. In color printing only three primary pigments are needed to produce all the different colors seen in colored advertisements. How is it possible to produce so many colors from the three primary pigments?
10. A lens is the most expensive part of a good camera. Why is a good lens so important? Why is it expensive?
11. The telescope and microscope are very important and useful instruments. The same thing is true for all optical instruments. If you can answer these questions you will be able to understand their operation. These questions are on the telescope:
    a. Is the objective lens of a telescope a long or short focus lens?
    b. Is the eyepiece lens a long or short focus lens?
    c. At what point is the real image of a distant object formed by the objective lens of the telescope?
    d. Is the image in part c erect or inverted?
    e. Is the eyepiece lens placed nearer or farther away from the real image than its focal length?
    f. Will the image seen through the eyepiece lens be larger or smaller than the real image? Is this image real or virtual?
    g. Will the image seen through the eyepiece lens be inverted or erect as compared to the real image formed? Erect or inverted as compared to the distant object?
    h. Is the real image formed in the telescope more or less bright than the distant object? Larger or smaller than the distant object?

The old

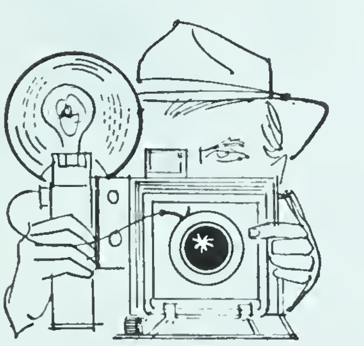
BECAUSE EARLY MAN LIVED MOST OF HIS LIFE OUTDOORS, there was no need for artificial light. Since he could neither read nor write, he had no need for light to see by at night. And all his necessary work was completed during the daylight hours.

When the need for artificial light arose, man invented methods of producing light, constantly finding better ways. The invention of the kerosene lamp was an improvement over the early lamps. The gas mantle and the incandescent light were improvements over the kerosene lamp.

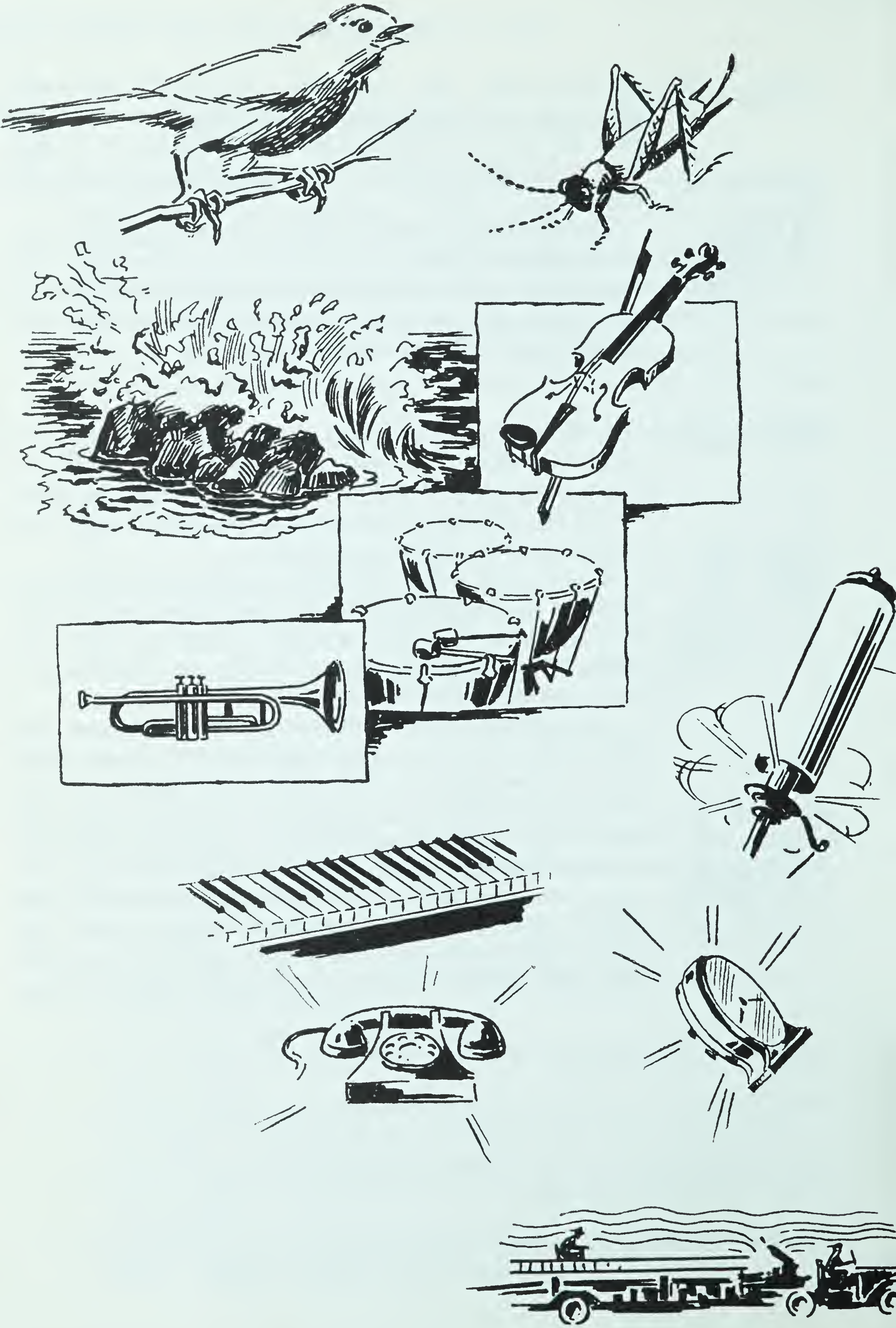
The new

THE MANUFACTURE OF GLASS MARKED THE BEGINNING OF the development of the study of light. It made possible the invention of lenses. These, in turn, made possible the invention of the telescope, the microscope, eyeglasses, camera, and all other modern optical instruments.

The invention of the telescope has given us information about the heavenly bodies. The microscope has made possible the observation of bacteria and other organisms. Most of us fail to realize how much the microscope has contributed to better and more healthful living.



Among many other optical instruments which have been developed is the camera. You are familiar with the recent advances in photography. Color pictures are an improvement over black and white. Your enjoyment of movies results from better lenses, cameras and projectors, and the development of colored pictures. Better cameras have also provided moving pictures which help make us understand more clearly what happens when we kick a football, hit a golf or tennis ball, play a musical instrument, or any other activity. Photography and motion pictures are among our largest industries today.



UNIT 10

How has man learned the nature of sound and music?

DISCOVERY AND PROGRESS

EARLY man produced sound by using his own voice. It took many years for him to learn how to make sounds that others could recognize. But once he had developed a simple language, he made great efforts to improve it.

Perhaps the sounds made by slapping and pounding grew with the early dances primitive man knew. Then he discovered that if he stretched an animal skin over a hollow log, the resulting sounds were even louder and pleasanter than the slapping and pounding. Thus the first drum came about.

Rattles also developed at this early age. Probably dried gourds with the seeds in them were first used. As they improved, castanets and tambourines were developed. Combinations of these early instruments later became gongs, cymbals, triangles, and all the related rhythm-makers.

The earliest string instruments were the harp and the lyre. Probably the twanging of a bowstring suggested how to make these instruments. They were later improved and the harpsichord and piano were evolved. Then it was found that a few strings, when the fingers were placed over them, could produce a variety of notes. This was the beginning of the violin family. Related instruments are the banjo, mandolin, and guitar.

The Greeks and the Chinese used a series of tubes bound together and blown on with the mouth—the "pipes of Pan." Our pipe organs were developed from these early instruments. Later someone discovered that a single tube, with holes bored along its length and covered with the fingers, produced a variety of different tones. From this crude instrument came the flute. When the vibrating reed was discovered, the clarinet, oboe, saxophone, and bassoon were made. Later they were improved by adding keys.

Further improvement was made by the invention of a system for representing musical tones and scales in printed form. This recording of music in printed form preserves the works of our great composers.

In 1877, while working on a telegraph instrument, Thomas Edison discovered the principle of the phonograph. His first crude instrument was turned by hand. Later a spring-driven motor was used, but this also had to be cranked by hand. Today, most phonographs are run by electric motors.

Our modern symphony orchestras have been made possible by the improvement of musical instruments of the past, and by the invention of a few new instruments. Much of this improvement has been due to the study of sound by scientists and by photographing sound waves produced by different instruments.

Big improvements were made in the telephone and phonograph, especially after sound waves had been photographed and their nature was known. Rapid progress has since been made. But even now, the telephone, phonograph, radio, television, and talking pictures fall short of completely natural reproduction.

Further progress is possible in the study of supersonic sounds. This may give us facts about sound vibrations not heard by the human ear. It may yet be possible to send them long distances.

Wave frequencies of several hundred thousand per second are frequently used. They are being used to sterilize foods without heating. Fog and smoke can be cleared with them. They can be used to detect flaws in metal castings several feet thick by reflecting waves through them. Some diseases can be cured by their bombardment. They can also be used to improve the productivity of seeds.

It is difficult to predict the many uses which will be made of these supersonic waves. Frequencies up to 12,000,000 per second have been produced.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How is sound carried from place to place? **2.** How is sound produced in a phonograph? **3.** Can sound be heard in a vacuum? **4.** What is pitch? **5.** Does sound travel faster in air than in iron? **6.** What produces sound in an organ pipe? **7.** How are the wires of a piano set in vibration? **8.** How is music different from noise? **9.** How are different notes secured in a slide trombone? **10.** What is the use of a violin bow? **11.** When a bell is rung, what produces the sound? **12.** What is the use of each part of the ear? **13.** What is a musical scale? **14.** What are the different types of musical instruments?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

amplitude . . . a measurement of the intensity or loudness of a sound wave.

compression . (kom-*preh*-shun), that part of a sound wave where the air particles are pushed close together.

echo . . . . reflected sound waves.

fundamental . the lowest tone produced when sounding body vibrates.

interval . . . . . the difference in vibration rates between two succeeding notes in a musical scale.

musical sound a sound that is pleasing to the ear because of its regular vibrations.

octave . . . . . . a series of vibration ratios in which the eighth tone has a vibration rate twice as high as the first tone.

overtone . . . . the tone produced when a sounding body vibrates in two or more parts.

percussion . . . (pur-*kuh*-shun), the act of striking a blow which sends out vibrations.

rarefaction . . (rare-uh-*fack*-shun), that part of a sound wave where the air particles are spread farther apart.

sound waves . waves of vibration by which sound travels.

stethoscope . . a device used to hear sounds inside the body.

vibration . . . . motion in matter which can produce sound.

A How are sounds produced?

Sounds are produced by the vibrations of matter. When you pluck a stretched rubber band, it vibrates and produces a sound. When you blow across the mouth of a bottle or test tube, or strike solid objects, you produce a variety of sounds. If such sound vibrations are regular, they are pleasing to the ear and are known as *musical sounds.*

DEMONSTRATION

Sharpen a match stick and hold it in one of the grooves of a revolving phonograph record. Result? Fasten the match stick firmly to the edge of a cardboard about 5 inches square. Hold the end of the match on the revolving record. Result? Which gives louder sound?

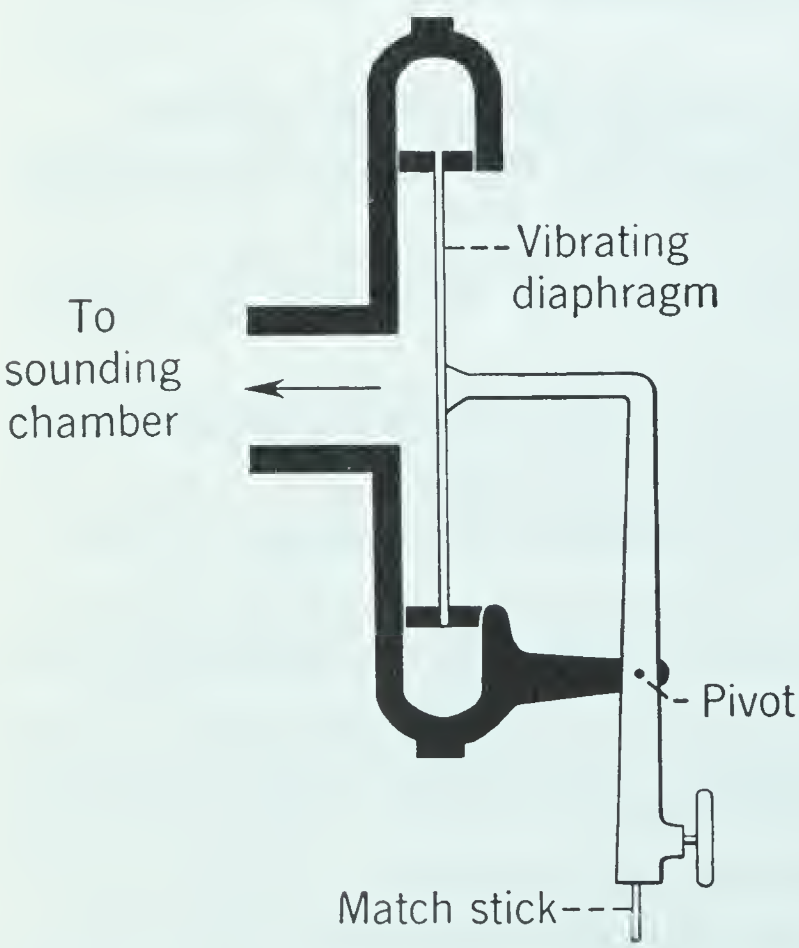


Fig. 10-1. The vibrating diaphragm sends out sound waves.

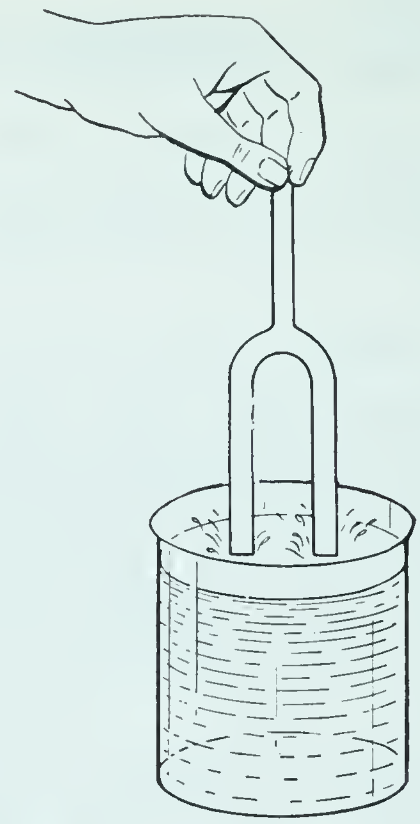


Fig. 10-2. The vibrations of the tuning fork in this demonstration cause the water to be set in motion.

Drive a metal phonograph needle through a thin piece of wood. Put the needle on the revolving record. Results? What is the use of the board?

Strike a tuning fork, then quickly lower the prongs into a dish of water (see Fig. 10-2). Result? What do you see on the surface of the water? Again set the fork vibrating and hold the prongs near your ear. Result? Again strike the fork and put the handle against the table. Result? Which produces the loudest sound?

Blow across the mouth of a six-inch test tube as in Fig. 10-3. Result? Fill the test tube about one-sixth full of water. Now blow across the mouth again. Result? Repeat, adding water to the test tube. Result?

Blow a whistle or pound a tin pan, or some piece of metal, or a board. What is the result in each case?

You can make matter vibrate in different ways. You can strike wires with a hammer or pluck them with your fingers or with a bow. You can set air in vibration with your lips, with reeds, or by jets of air. You can also make water vibrate by putting some vibrating object into it. You can even make gases vibrate.

The ordinary human ear is affected by vibrations having rates between 20 and 16,000 per second. When you wave your hands back and forth, they are vibrating in a way. However, no sound is heard because the vibrations are not fast enough.

A dog can respond to sounds that you cannot hear because his ears are sensitive to higher rates of vibration than yours can receive. Perhaps you have seen the special type of dog whistle whose sound cannot be heard by humans.

A vibrating object makes the air around it vibrate. When a body vibrates, it sets up a wave motion in the surrounding air. The vibrating object makes the air vibrate and produces a series of waves which move back and forth. These are carried in all directions from the vibrating body.

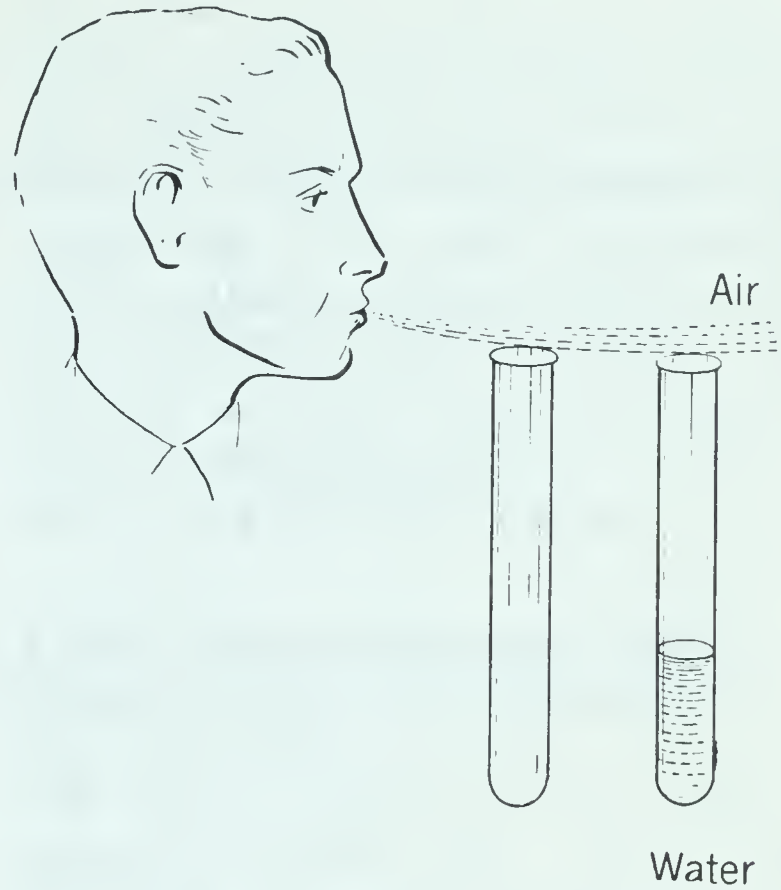


Fig. 10-3. Blowing across the mouths of these test tubes causes the air in the tubes to vibrate.

Sound waves consist of two parts. These are: (1) the *compression* (kom-*preh*-shun); and (2) the *rarefaction* (rare-uh-*fack*-shun). ***Compression*** is the part of the wave where the air particles are pushed closer together. If you clamp one end of a stick to a table and push the other end down quickly, the air under the stick is pushed downward and outward.

Rarefaction is the part of the wave where the air particles are farther

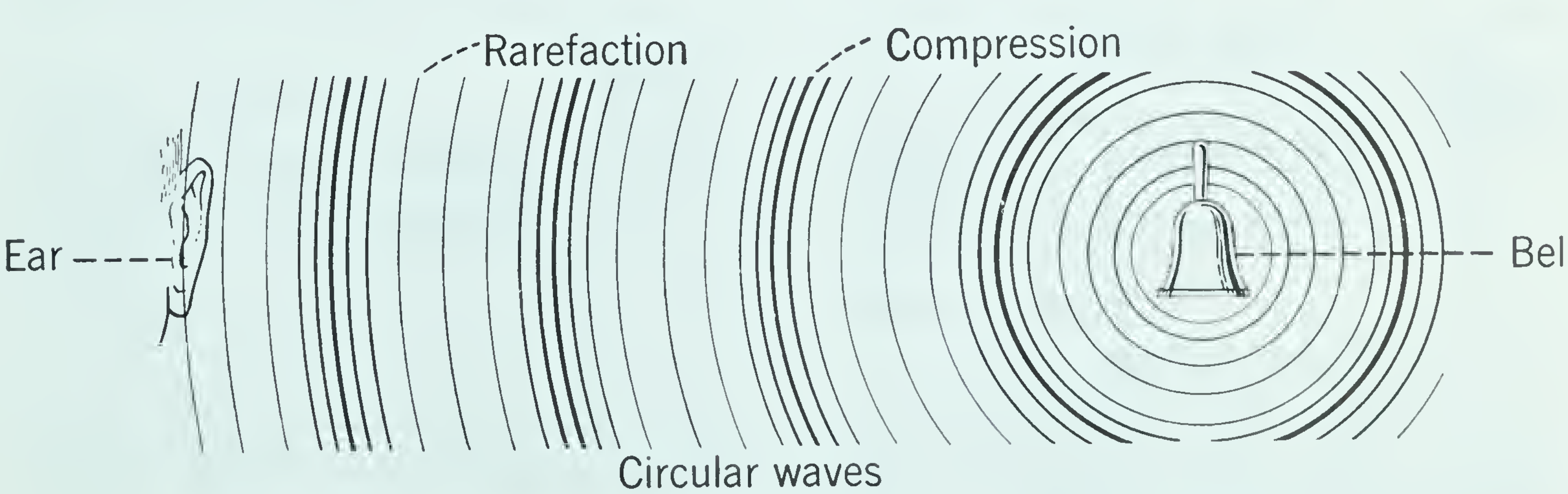


Fig. 10-4. Sound waves are a series of rarefactions and compressions.

apart. In the stick just mentioned, the space above the stick will have a lower air pressure and the air particles will be farther apart. When the stick bounces up, there will be a compression above it and a rarefaction under it. Compressions and rarefactions will follow each other as fast as the stick vibrates. Air is not only pushed up and down, but also back and forth in all directions.

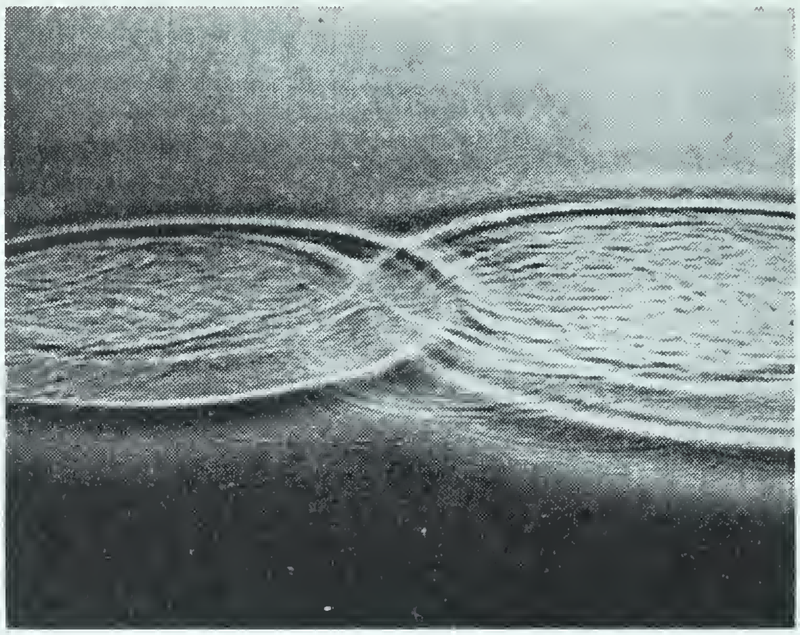


Fig. 10-5. Sound waves move away from a vibrating body much the same way as water waves do when you drop a pebble into the water.

Sound waves move away from a vibrating body. They move as ripples or waves move away from the spot where you have thrown a stone into the water. The difference between these two types of waves is that sound waves travel in all directions, while water waves travel only on the surface of the water.

The loudness of a sound depends on the amount of matter that vibrates. The waves are higher in water if you drop a large stone because more water is suddenly pushed aside. In the same way, the more air an object causes to vibrate, the louder will be the sound. A loud-speaker sets more air in motion, thus producing a louder sound.

Loudness is due to ***amplitude.*** In the diagram in Fig. 10-7, the amplitude is the height of the wave from the center to the top or bottom part of the wave. As the height of the wave becomes less as it moves away, so the loudness of sound decreases as you move away from the source. When sounds are made louder, as in a radio amplifier, the wave amplitude is increased. This is done by using a greater amount of energy to produce the sound vibrations.

The number of times an object vibrates per second is its ***frequency of vibration.*** The frequency of vibration determines the pitch of a sound. By

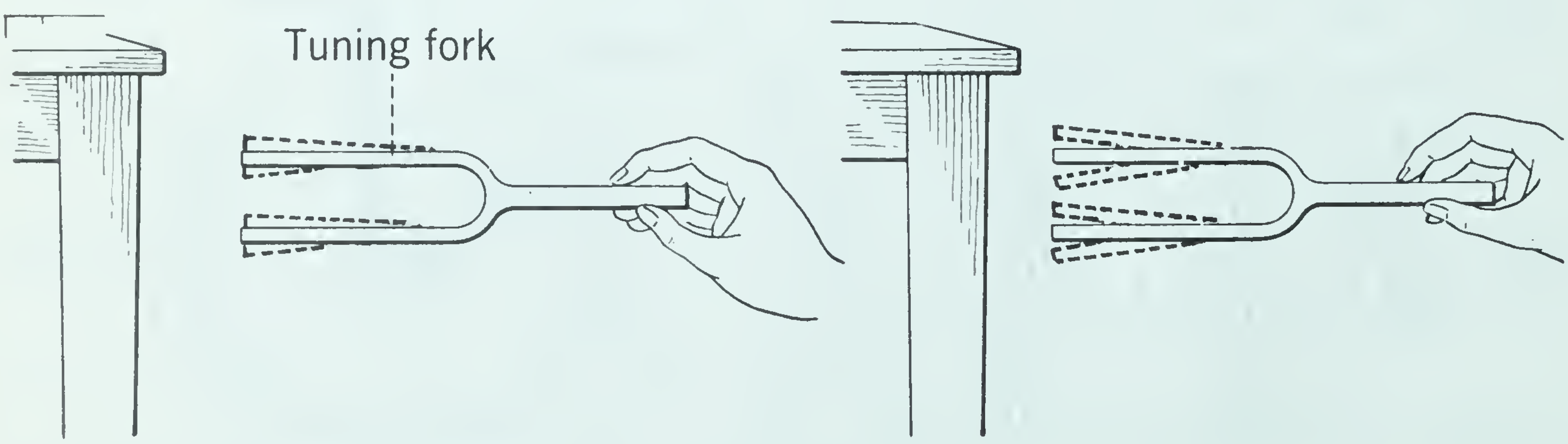


Fig. 10-6. The harder you strike a tuning fork, the more the air is set in vibration and hence the louder the sound is.

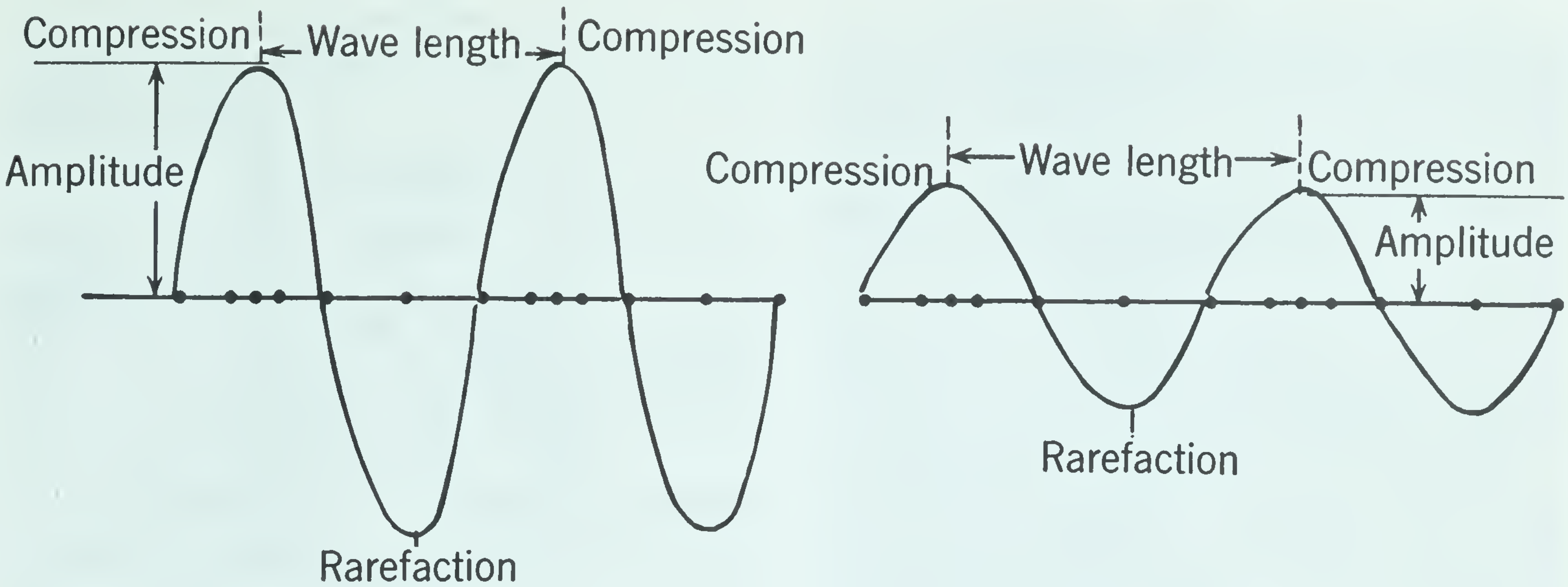


Fig. 10-7. This curve is often used instead of the waves in Fig. 10-4. Although the pitch is the same, the sound on the left is louder than that on the right because of its greater amplitude.

pitch we mean how high or low the sound is. If you strike a C tuning fork against your hand or knee, its prongs will vibrate 256 times a second. No matter how hard you hit the fork, it will still vibrate 256 times a second. The pitch of the tone will stay the same. What did you change when you hit the fork harder? How might you change the pitch of the tuning fork?

A *wave length* is the distance from the top of one wave to the top of the next succeeding wave, as shown in Fig. 10-7. When you strike a tuning fork, the rate of vibration (frequency), and the wave length are constant. The amplitude or loudness of the sound depends on the force of the blow.

REVIEW QUESTIONS

1. What is sound? **2.** How are sounds produced? **3.** What is pitch? Loudness? Amplitude? **4.** What is a wave length? **5.** What are the lowest and highest rates of vibrations that the human ear hears? **6.** How does a loud-speaker make sounds louder? **7.** What are the parts of a sound wave?

B How are sound waves carried from one place to another?

Sound waves are usually carried to our ears by the air. Have you heard the shot of a gun fired at quite a distance from you? How did the sound waves get from the gun to your ears? You probably have noticed that when you strike two stones against each other under water, you can hear the sounds produced under water.

Gases, liquids, and solids carry sound waves. Some simple experiments will help you to understand why. At the same time it will test your hearing ability.

DEMONSTRATION

Set an alarm clock on a thick pad of cotton which is put inside a bell jar, as in Fig. 10-8. Let the alarm clock ring. Notice its loudness. Again, wind the clock

and put it in the bell jar while it is ringing. Remove the air with a vacuum pump. Result? Let air in. Result? Will sound waves pass through a vacuum? What is one form of matter that will carry sound waves?

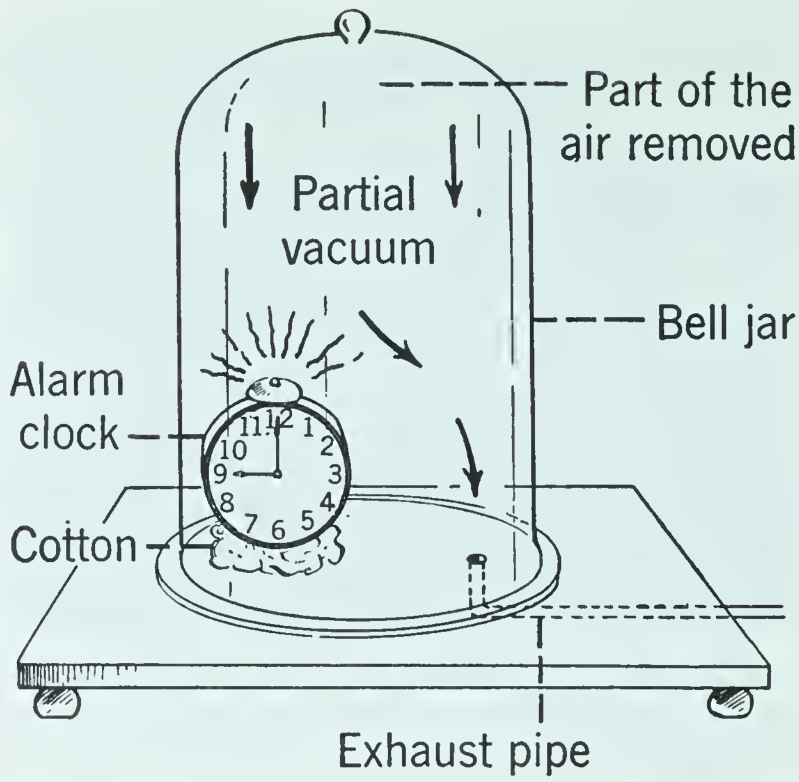


Fig. 10-8. When the air is removed from the bell jar, you cannot hear the bell ring. Sound does not travel through a vacuum.

PUPIL ACTIVITY

Hold your ear close to one end of an iron pipe while someone scratches the other end with a pin. Result? Repeat, using a wooden pole about the same length. Result? Repeat the experiment by using two poles equal in length to the one pole. Leave a small gap between the two poles as in Fig. 10-9. Scratch the end of the pole farthest away from your ear. Result? Explain.

Make a toy telephone out of two tin cans and a piece of wire or string at least 100 feet long. Fasten the string or wire through holes in the bottom of the cans and knot the ends to prevent them from slipping through. Talk to a friend in as low a tone as he can hear. Now talk in the same tone over your simple telephone. You should stretch the wire or string very tight. Result? What carried the sound waves?

These demonstrations show that we need some form of matter to carry sound. Sound waves will not pass through a vacuum. Wood and iron carry them better than air or water. On the other hand, they travel faster in water than in air. Two rocks tapped together produce a sound that travels faster under water than in air.

Sound travels in air at a speed of approximately 1,100 feet per second. When you see a flash of lightning a mile away, the speed of light is such that the flash reaches your eye almost instantly. The sound of the resulting thunder reaches your ear later. By using an accurate stop watch, you can measure the interval between flash and

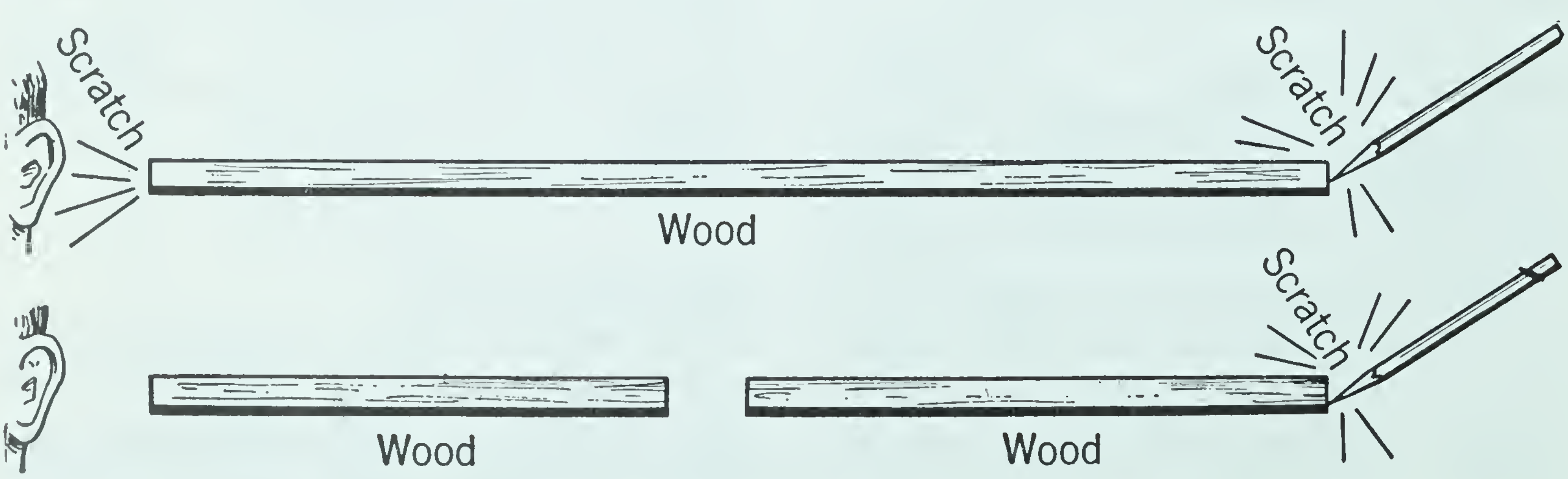


Fig. 10-9. These experiments show that wood carries sounds better than air.

thunder. A rocket soars into the sky. You see the flash. Does the report come at once?

In the 100-yard dash, the timekeeper first sees the flash of the gun rather than hears the sound of the shot. He starts his stopwatch when he sees the flash instead of when he hears the shot. Why?

At ordinary temperatures sound waves travel about 1,100 feet per second in still air. They travel faster in water, and still faster in solids such as wood, stone, and iron. When the temperature of air rises, the speed of sound increases. Sound travels slower at high altitudes than it does near the earth's surface. Why?

Sound waves can be reflected. You no doubt have noticed that when you shout toward a distant wall, the sound is reflected back to you. We call sounds reflected in this way *echoes*.

The ear cannot distinguish between direct sound and its reflected sound if they are less than one-tenth of a second apart. Sounds in small rooms are reflected back in time to blend with the original sound, and thus there is usually no noticeable echo. If the room is more than 55 feet long, echoes are produced which interfere with the original sounds.

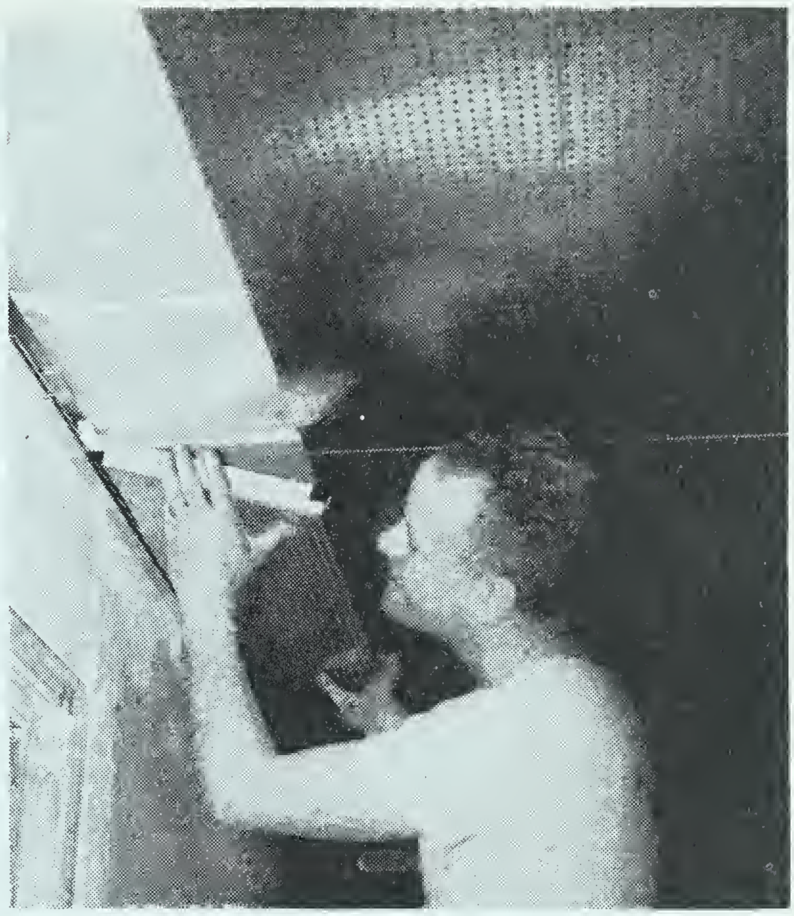


Fig. 10-11. Here a workman is installing perforated material on the ceiling to reduce echoes in the room.

Auditoriums are now built with rounded corners and few large flat surfaces. This prevents sound waves from being reflected to any one position. They are scattered in many directions and the only sounds heard are those sent out from the source. Many materials are made which absorb vibrations or break up the waves. Some fiber-

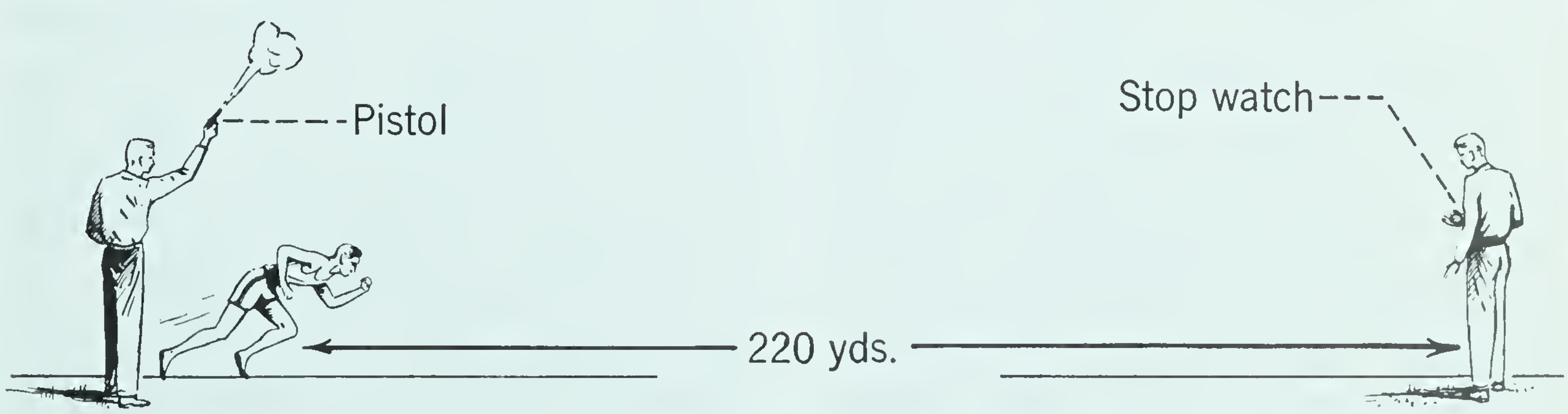


Fig. 10-10. A timekeeper times a race from the flash of the gun, and not from the sound of the shot.

Fig. 10-12. Orchestra shells are built in this shape with sound-reflecting materials. This construction enables outdoor audiences to hear the music clearly.

boards having many holes are used to soundproof rooms. Again the waves are either absorbed or scattered so there is very little reflection.

We find today that in modern buildings the architect uses methods and materials which reduce echoes and favor good sound transmission.

REVIEW QUESTIONS

1. How are sound waves carried from one place to another? **2.** With what speed do they travel in air? Compare the speed of sound waves in air, water and iron, or steel. **3.** Compare the distances sound can be carried by the different forms of matter. **4.** Why can the flash of a distant gun be seen before the sound is heard? **5.** Under what conditions are echoes formed? **6.** What kinds of materials are used to soundproof a room? How do these materials deaden sound vibrations?

C How do your ears hear sounds?

Our ears and auditory nerves change air vibrations into sensations of sound. When sound waves (vibrations) reach the outer ear, they are directed through a canal to the *eardrum* which separates the outer ear from the middle ear. The waves cause the eardrum to vibrate. This vibration is carried to three tiny bones in the middle ear: the *hammer, anvil,* and *stirrup*. These in turn carry the vibrations to the *cochlea* (*kok*-lee-ah) which is in the inner ear.

Fig. 10-13. These students are having their hearing tested with an audiometer. They indicate on a piece of paper whether or not they hear a sound.

The cochlea is a spiral structure filled with a liquid and lined with nerve endings. The liquid in the cochlea vibrates and stimulates the nerve endings. They send the impulses to the *auditory nerve* which carries the impulses on to the brain. This gives us the sensation of hearing.

PUPIL ACTIVITY

Examine a model or diagram of the ear (see Fig. 10-14). Find the external ear, the middle, and the inner ear. Note the shape of the external ear. Can you tell what it does? Find the eardrum. What is its use? Find three small bones in the inner ear, known as the hammer, anvil, and stirrup. Note how they form a chainlike connection with the parts of the inner ear.

Find the *Eustachian* (you-*stay*-kee-an) *tube* which connects the middle ear with the throat cavity. This tube lets in air to the middle ear so the air pressure is equalized on both sides of the drum. Without this opening, changes in air pressure of the atmosphere would cause distortion of the sounds that reach the eardrum. Find the cochlea and the auditory nerve. How are sound vibrations transmitted from the outer ear through the middle ear to the inner ear?

Your hearing can be tested. Because poor hearing can develop gradually, you should have your hearing tested occasionally. Poor hearing can often be corrected if discovered early enough. Sometimes parts of the ears become filled with wax, or they may be infected. Both conditions can be remedied.

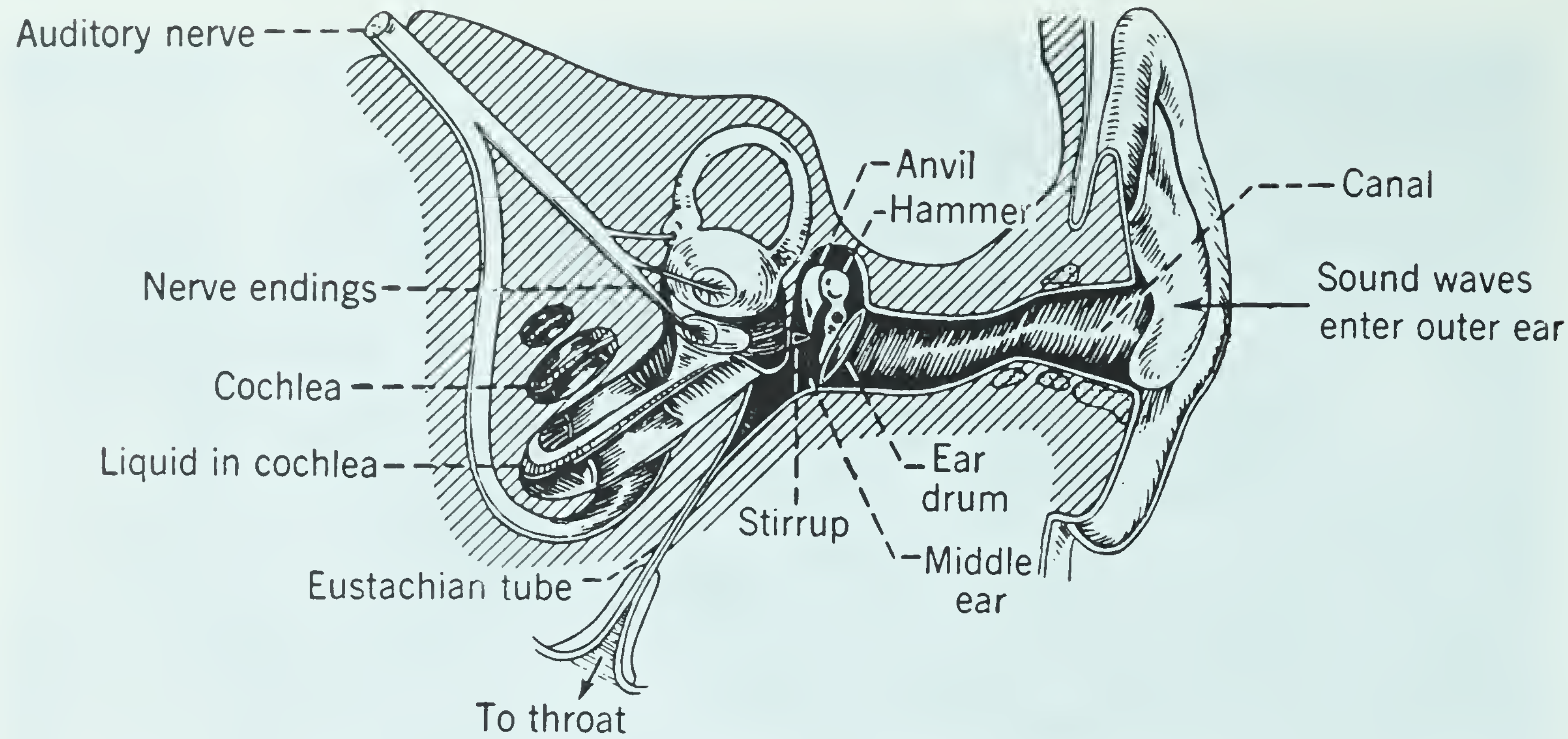


Fig. 10-14. Trace the sound waves from their entrance at the outer ear to the auditory nerve.

PUPIL ACTIVITY

To make a rough test of your hearing, have a friend hold a watch near one ear and then find out how far away the watch can be carried before you cease to hear it tick. Test the other ear in the same way. Results? Can you hear as well with your right ear as with your left? Test your friend's hearing and compare the results. Hold a watch between your teeth. Is the ticking faint or loud? Close both ears with cotton and compare with your former results. Keeping the cotton in your ears, hold the watch against the bony part of the nose. Result?

There have been a number of inventions in recent years to help the hearing. Hearing aids have helped many people and are inconspicuous to wear. *Audiphones* (*aw*-dee-fones) are devised to catch sounds made by airplane propellers long before the ear can pick them up. Sound detectors are used for locating the position of submarines. Doctors note the sound of the heartbeat and other body sounds with a *stethoscope* (*steth*-oh-scope).

REVIEW QUESTIONS

1. What are the parts of the ear? **2.** How does the ear hear sounds? **3.** What are some of the recent inventions to improve hearing? **4.** What aids are being used to make sounds louder?

D What are the characteristics of musical sounds?

The pitch of a musical sound depends on its rate of vibration. Sounds can have a high or low pitch. The keys of a piano produce sounds by vibrating strings. Each string has a definite, fixed rate of vibration, different from that of the other strings.

In the human *voice box* in the throat

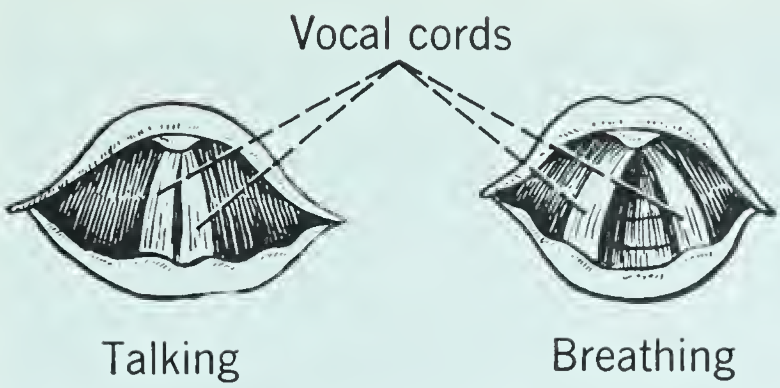


Fig. 10-15. The vibrations of the vocal cords produce sounds.

there are two strings called the *vocal cords.* They vibrate when air is blown against them from the lungs. Their rate of vibration changes when they become either tense or loose, depending on the action of the muscles of the voice box.

When a boy matures, his voice changes because his vocal cords get larger and thicker. This produces sounds of a lower pitch. A girl's voice does not change much because there is little growth of her vocal cords as she grows up. For this reason, women's voices are usually higher in pitch than men's.

We tune musical instruments by making the pitch of one note agree with some standard. This standard is a tuning fork or some piano note. In stringed instruments, the various strings are tuned so that their pitches will have the correct relation to that of a tuning note (usually an A of 440 vibrations per second).

Sounds can be produced by percussion. In percussion (per-*kuh*-shun) instruments like drums, air is set in vibration by beating the drum. But the sounds are of no definite pitch, except in the case of kettledrums. Drums are used mostly to keep time. The larger the drum, the louder the sounds it makes. Bells, drums, cymbals, triangles, and castanets are all percussion instruments.

Strings can be made to vibrate by plucking, bowing, or striking. Strings for musical instruments are usually made of wire, catgut, or synthetic material like nylon. Such instruments are called stringed instruments. Familiar

Fig. 10-16. In a symphony orchestra, harmonious sounds are produced by the skillful blending of brass, string, reed, and percussion instruments.

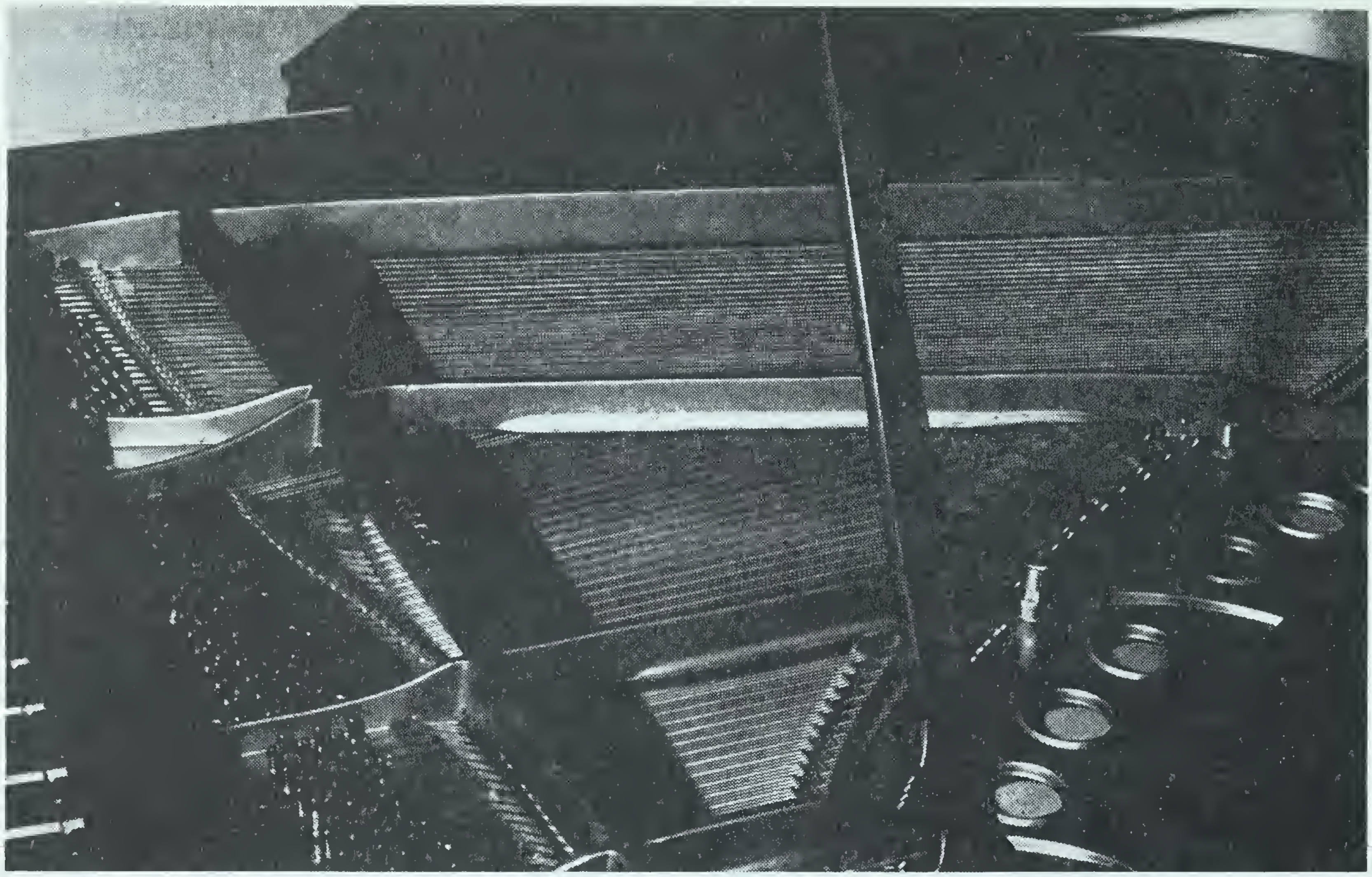


Fig. 10-17. Notice in this photograph of piano strings that the longer strings at the top are not only thicker but are also wound with wire so they can produce the lower tones.

examples are the piano, harp, violin, cello, viola, bass viol, banjo, mandolin, and guitar.

In designing stringed instruments it is necessary to provide for a wide range of musical notes. In a piano this is done with wire strings of different length, diameter, and tension. Small hammers controlled by the piano keys, set the wire strings vibrating.

In some stringed instruments, the length of the vibrating strings is changed with the fingers. By having a few strings of different size and tension, you can produce a wide range of notes. The friction of the bow sets the strings of the instrument in vibration. The harp has a wire string for each note, but the length of the strings can be varied by the action of pedals. Its strings are set in vibration by plucking.

The pitch of a string depends on its size, length, and tension. A stringed instrument must produce tones of different pitches. We can do this in three ways: (1) by changing the length; (2) by changing the size; or (3) by changing the tension of the strings. Usually combinations of these methods are used. Simple demonstrations will show us how pitch is affected in these ways.

DEMONSTRATION

Stretch a wire on the sound board as in Fig. 10-18. Pluck the wire. Increase the tension on the wire by turning the screw or by adding weights to the end of the wire. Pluck the wire again. How does an increase in tension affect the pitch?

Put a bridge underneath the center of the stretched wire, without changing the

tension. Pluck the wire. Compare the pitch of a short wire with that of a long wire. Put another bridge under the wire so that the length of the wire is one-fourth its original length. Pluck the wire again. Result? How does the length affect the pitch?

If possible, get two wires, one having twice the diameter of the other. What weights do you need to produce the same pitch in each? Explain.

The pitch of a wire is raised if you shorten it, the tension remaining the same. The pitch is also raised by increasing the tension of the string if there is no change in length. A thick wire will have a lower pitch than a thin wire of the same length and tension. In tuning stringed musical instruments the tension is changed.

Vibrations are produced in wind instruments by reeds, lips, and blowing jets of air across narrow openings. The sound of wind instruments is not so varied or flexible as that of some stringed instruments. Pitch is changed in them in two ways: (1) by changing the length and size of the air column; and (2) by using open or closed tubes. The extremely high or low notes of the wind instrument's range are often of poor quality.

You can change the length of the air column by closing openings with keys and fingers, as in the clarinet, oboe, saxophone, and flute. In the trombone this is done by moving a sliding U-shaped tube back and forth. In the trumpet and horn, valves admit air to tubes of various lengths. In the organ, pipes of different lengths are used. In playing wind instruments, you must know what length of air column

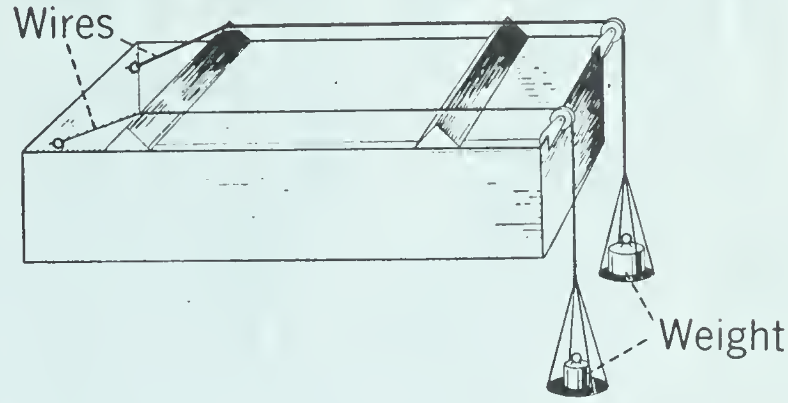


Fig. 10-18. When you add weights to the wire, the tension is increased and the pitch is higher.

will produce the pitch desired and what use of your lips will produce pleasing sounds.

Sounds of different pitch in wind instruments are produced by using columns of air of different lengths and sizes. To produce a complete range of sounds in a pipe organ, you must have a large number of pipes. Each pipe will produce a note of a certain pitch. In brass wind instruments, like the trombone and trumpet, you can change the lengths of air columns. You can also produce a certain number of different notes by variation in blowing and lip tension.

The following demonstrations show you how the pitch is changed when you change the length of the air column.

DEMONSTRATION

Get four test tubes of the same size and length (see Fig. 10-20). Blow across the mouths of the four tubes. Result? Fill one test tube one-fourth full of water, another one-half, another three-fourths full. Leave one empty. Blow across the open ends of the test tubes. Result? In which was the highest pitch produced? The lowest? How is pitch related to the length of the vibrating column of air?

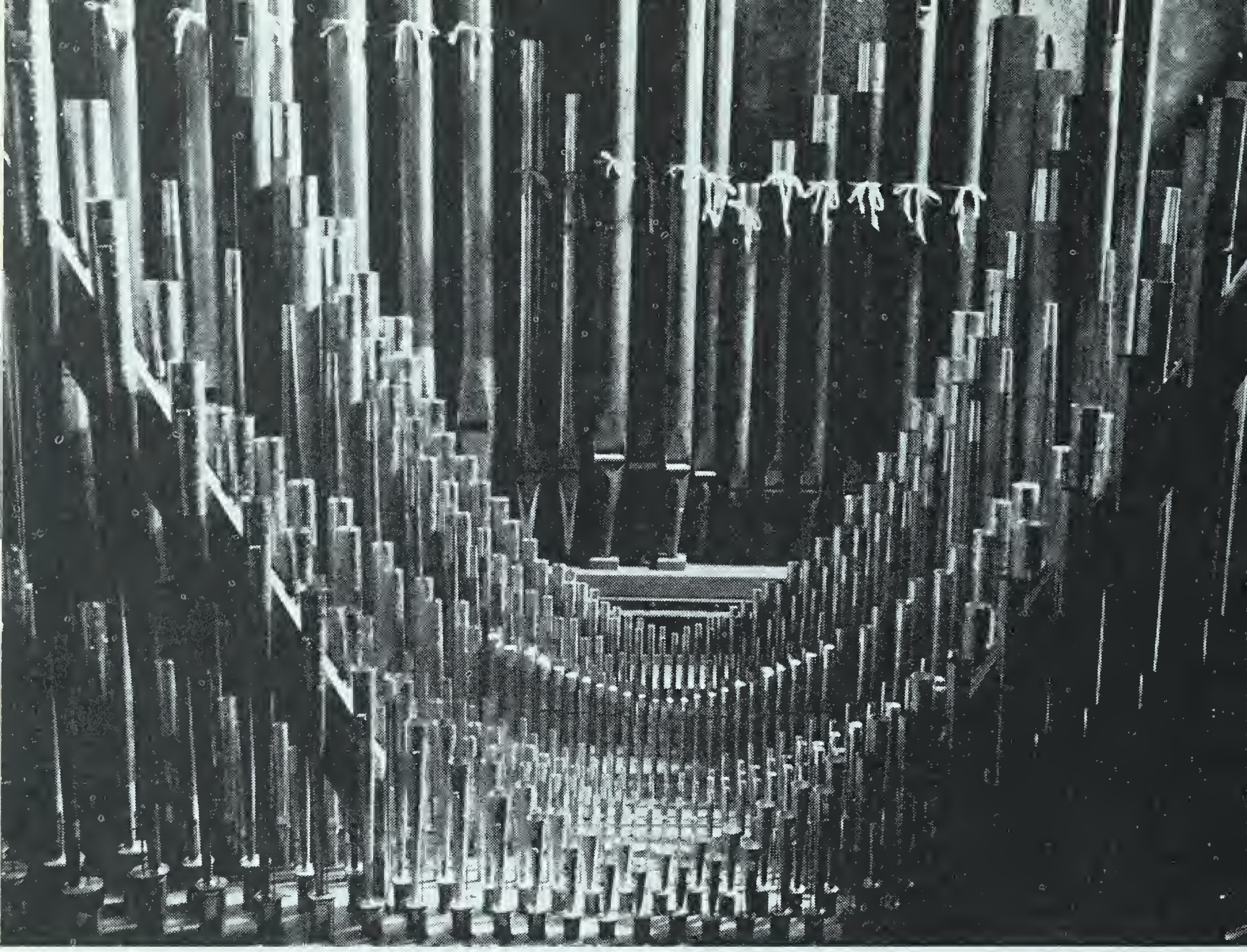


Fig. 10-19. These organ pipes all have different lengths, different shapes, and are made of different materials. The pipes shown here are enclosed within the organ. The large visible pipes of many organs are decorative, and do not produce sounds.

Take two test tubes of equal lengths but of different diameters. You can make the lengths of the air columns the same by filling one partly full of water. Blow across the open ends. Result? Which produces the higher pitch?

The length and size of the air column determines the pitch of a note in wind instruments.

Loudness of a sound depends on the amplitude of the sound waves. It is difficult to carry sound waves over long distances. This is because they spread in all directions and their amplitude decreases rapidly. A horn or megaphone is often used to direct the sound waves in a desired direction. The range

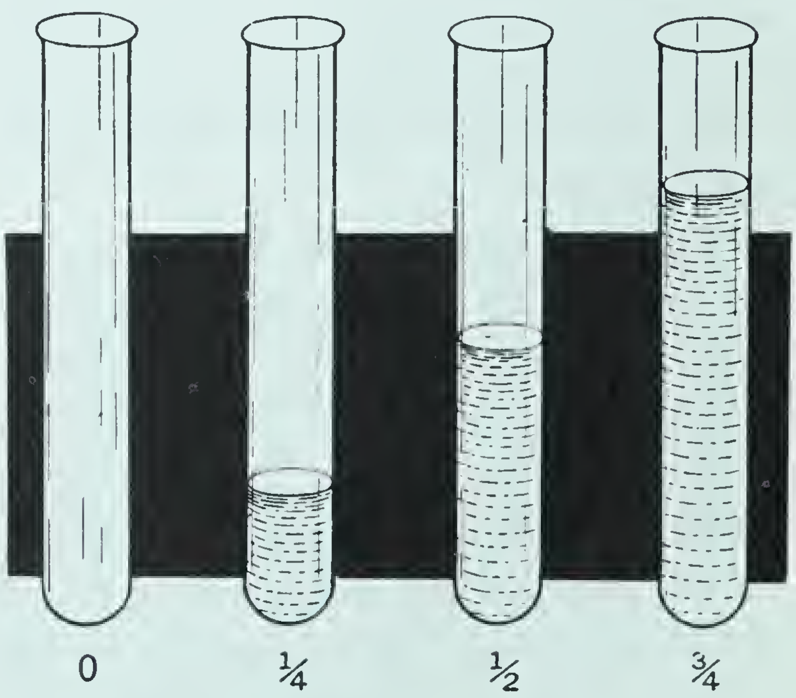


Fig. 10-20. The shortest column of air produces the highest rate of vibration and the highest pitch.

of such instruments is limited by the loudness of the original sound.

If you strike a tuning fork and hold it near your ear, you can hear the sound. If you hold the handle of the fork against a table, the loudness will increase. The table is set in vibration and it in turn sets a large volume of air in vibration. Sounding boards are used to increase the loudness of many musical instruments in the same way.

Sounds can be reproduced mechanically. The mechanical reproduction of musical sounds has been improved in recent years, but it nears perfection only when you use the finest equipment. The telephone, phonograph, radio, television, and sound pictures reproduce many of the higher tones, but not all of them.

In making records a wax plate is etched by the recording instrument. A master record is made and duplicates are made from it. In recent years a much better way of making sound recordings has been developed. By using a special type of electromagnet, it is possible to make a recording on a plastic tape coated with a very thin layer of iron oxide. Tape recorders make it possible to reproduce a great variety of sounds in the home and at school. If your school owns a tape recorder, it would be interesting to study how it works.

REVIEW QUESTIONS

1. What determines the pitch of a sound? **2.** How are notes of different pitch produced by the human voice, by a piano, and by a pipe organ? **3.** How is the pitch of a wire affected by changing its

Fig. 10-21. Tape recorders are often used today in offices, homes, and schools.

length and tension? **4.** What do we mean by the loudness of a sound? **5.** How is the loudness of a sound increased? **6.** How are sounds of different pitch produced in each of the following instruments: piano, violin, pipe organ, clarinet, cornet, trombone, mandolin, and harp? In what part of each instrument are the vibrations produced?

C	D	E	F	G	A	B	C′	D′	E′	Letter names
Do	Re	Mi	Fa	Sol	La	Ti	Do′	Re′	Mi′	Syllable names
256	288	320	341	384	426	480	512	576	640	Vibration rates
1	9/8	5/4	4/3	3/2	5/3	15/8	2	9/8	5/4	Vibration ratios

Fig. 10-22. This diagram shows the major scale, key of C.

E How are musical scales constructed and played?

Most sounds are complex. If a sound is produced like that in a tuning fork, there is only one rate of vibration. If different rates of vibration blend together to make a pleasing sound, we say it is *musical*. The problem in making the sounds pleasing is how to produce these sounds in the proper combinations of vibrations.

Musical scales are built on simple mathematical ratios. The most pleasing combination of sounds has the ratio of 1 to 2. If a tuning fork with a vibration rate of 256 is sounded together with a tuning fork of 512 vibrations per second, a harmonius sound is produced.

The next most pleasing combination is the ratio of 2 to 3, or 256 vibrations with 384 vibrations per second. Sounds in a major chord have the ratios of 4 to 5 to 6 or 256 to 320 to 384 vibrations per second. In a minor chord, these ratios are 10, 12, and 15.

All scales have eight notes which make up an *octave.* The last note in an octave has a vibration rate twice as high as the first. No matter what rates of vibration we use, the ratios stay the same.

In the diagram in Fig. 10-22, the letter names, syllable names, vibration rates, and ratios are given for an octave in the major scale. In this diagram of the key of C, the scale begins with the note C. C has 256 vibrations per second, as you have already learned. Each vibration ratio is multiplied by 256 to give the vibration rate of each letter.

DEMONSTRATION

Sound two tuning forks of different frequency together. Try several combinations. Which combinations produce the most pleasing sounds? Which is the most discordant? These different rates of vibration can be produced on the piano. Next, try sounding three tuning forks together, such as C, E, and G; E, A, and C; of G, B, and D; and C, D, and F. Which combinations are the most pleasing? The most discordant?

Add water to eight test tubes as shown in the diagram in Fig. 10-23. If the test tubes are filled to the proper depths, the eight notes in the octave can be produced by blowing across the tops of the tubes.

Key	C	D	E	F	G	A	B	C′	D′	E′
C	256	288	320	341	384	426	480	512		
D		288	324	360	384	432	480	540	576	
E			320	360	400	427	480	533	600	640
Number of keys	1	1	2	2	2	2	1	3	2	1

Sounds are produced by forcing the air in the tubes to vibrate. The lips act like a reed. The lengths of the air columns in the tubes should be in reverse ratios to the rates of vibration of the different notes in an octave. That is, the shorter air columns produce the higher notes.

An octave can begin with any rate of vibration. No matter where it begins, the ratios must be kept the same for each succeeding note. In a musical scale each succeeding octave has a rate of vibration twice that of the preceding octave. However, the same ratios are maintained in all the octaves. The human voice has a range of 3 to 4 octaves. The piano has a range of over 7 octaves.

To produce harmonious sounds, we should be able to begin with any key in an octave and keep the same vibration ratios. If we should do this with a major scale, we would have to have nearly 200 keys to play the complete range on the piano keyboard. The table on this page shows us what happens when three musical keys are used as the beginning points. You can see that it will take 17 piano keys to play one octave using only three keynotes.

The piano uses a simplified musical scale. This is called the ***even-tempered scale.*** In this scale there are 13 notes in an octave with 12 intervals. An ***interval*** is the ratio or difference in vibration rates between two succeeding notes in an octave. The piano uses 8 white keys and 5 black ones for an octave.

The diagram in Fig. 10-24 gives the different vibration rates for each key on the piano on the even-tempered scale. The standard pitch of 440 vibrations per second is taken for A.

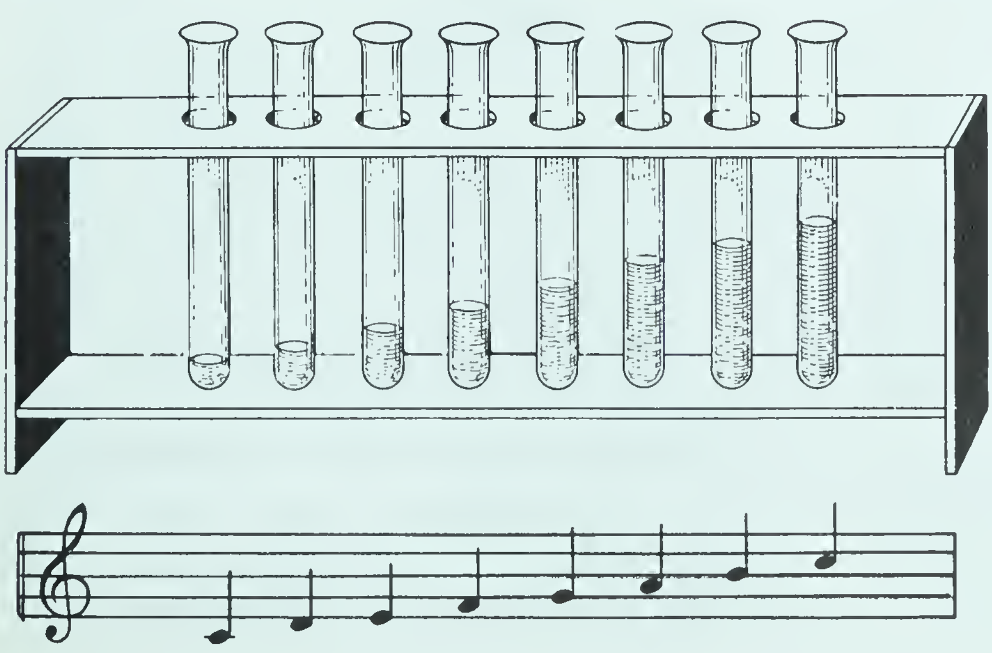


Fig. 10-23. The eight notes in an octave can be produced in the test tubes if the lengths of the air columns are in the correct proportions.

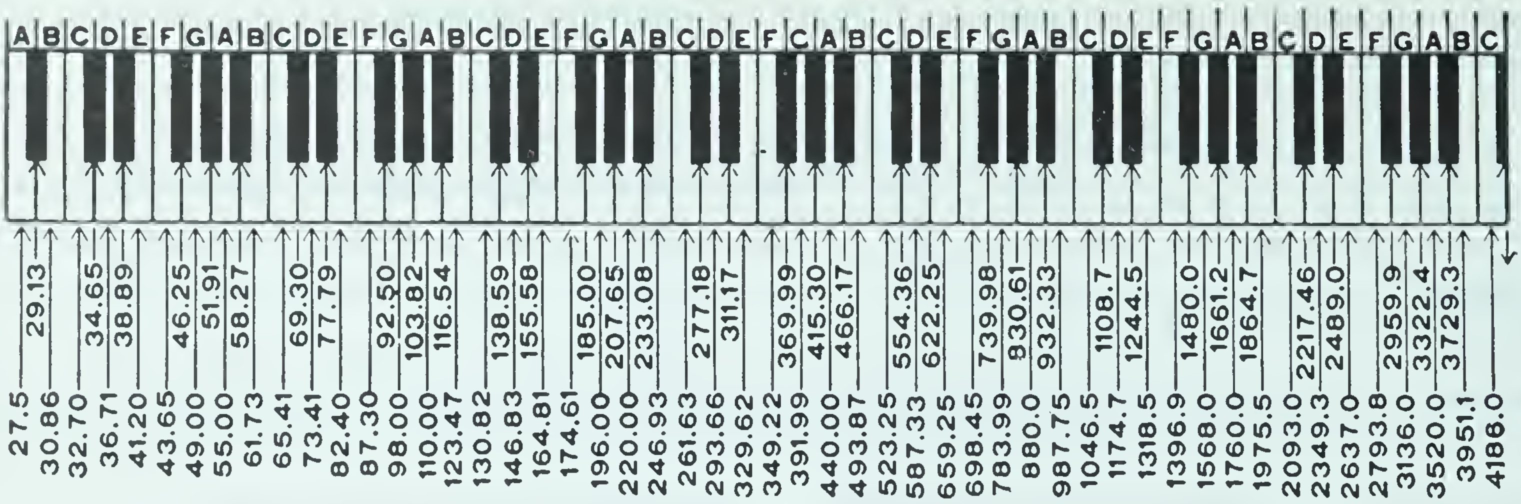


Fig. 10-24. Here you can see the vibration rates for the different keys on a piano on the even-tempered scale. There are eight white and five black for each octave.

Timbre or quality depends on the mixture of vibrations of different rates in a sound. The difference between two sounds of the same pitch and loudness is called *timbre,* or quality. The sound of the violin is different from that of a pipe organ or the human voice. Strings and air columns can vibrate as wholes or in parts at the same time. If a string vibrates as one part, the lowest tone, or *fundamental,* is produced (see Fig. 10-25).

A string can also vibrate in two parts at the same time as it vibrates in one part. The halves vibrate twice as fast as the whole string. The vibrating halves produce the *first overtone.*

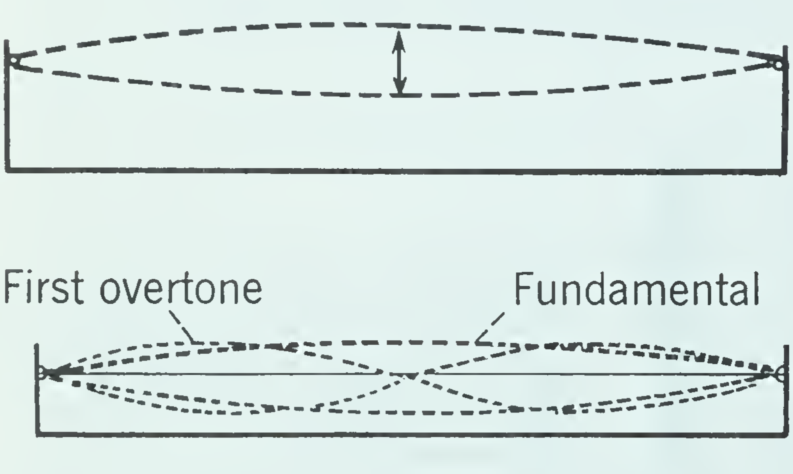


Fig. 10-25. (Top). A wire that vibrates in one part produces the lowest tone, or fundamental. (Bottom). A wire that vibrates in two parts produces the first overtone.

In the *first overtone,* the rate of vibration is twice as rapid as the fundamental (see Fig. 10-25). Strings can also vibrate in three or more parts and as a whole. The *second overtone* is produced when a string vibrates in three parts. Its rate of vibration is three times the fundamental. In this way, many overtones can be produced. If these overtones give a pleasing sound we say they are *harmonious;* if not, they are *discordant.* In any case, they produce the characteristic quality of sounds and voices. The material used to make an instrument and the manner of playing on it both affect the quality of the sound.

REVIEW QUESTIONS

1. What do we mean by a complex musical sound? **2.** Why are musical scales built up of simple mathematical ratios? **3.** What is an octave? **4.** What are the notes in one octave on the major scale? **5.** Why was the even-tempered scale constructed? **6.** What are the advantages and disadvantages of the even-tempered scale? **7.** Explain why a saxophone sounds differently from a trombone, even though they play a note of the same pitch.

QUESTIONS FOR REVIEW AND DISCUSSION

1. What is sound? How are vibrations produced?
2. How are sound waves carried from one place to another? What is the speed of sound in air? Is it the same under all conditions?
3. What is the difference between a noise and a musical sound?
4. What are the upper and lower limits of hearing? What is the rate of vibration for each?
5. How is the air around a vibrating body set in vibration?
6. How does a phonograph reproduce sound? When and by whom was the phonograph invented?
7. What do we mean by the pitch of a sound? By the loudness of a sound?
8. What is the purpose of sound amplifiers? On what principle do they operate?
9. What is the principle of the megaphone? Under what conditions is it used?
10. What are the parts of the ear? What is the function of each part?
11. Why do you see the flash of a distant gun before you hear the sound of the explosion?
12. If the sound of thunder was heard five seconds after you saw the flash of lightning which caused it, how far away was the lightning?
13. What are echoes? Under what conditions are they produced? How can they be prevented in a room?
14. What are the three characteristics of a musical sound?
15. What determines the quality of sound?
16. How are violins tuned?
17. Why are the pipes of some organs kept in rooms in which the temperature is controlled?
18. Why are the wooden blocks of a xylophone of different sizes?
19. In what three ways can the strings of stringed instruments be set in motion?
20. In what different ways can air columns be set in vibration?
21. What arrangements are used in stringed instruments to get sounds of different pitch? To increase the loudness? To produce overtones?
22. Why is it difficult to reproduce sound mechanically?
23. How is the fundamental tone produced in a wire? The first overtone? The second overtone?
24. Why do symphony orchestras have a wide variety of instruments?

25. How do musical instruments get out of tune? How are they tuned?
26. What are the uses of a doctor's stethoscope?
27. Why can a stringed instrument which is in tune in a warm room be out of tune when taken into a cold room? Will the pitch be raised or lowered?
28. How are vibrating reed instruments tuned?
29. How does the human voice produce sounds of different pitches?
30. Why are the members of an orchestra or choir placed as near together as possible and in a semi-circle?

SPECIAL REPORTS AND PROBLEMS

1. Demonstrate how some musical instrument is played, and explain the process.
2. Report on the construction of some musical instrument.
3. Report on sound amplifiers and how they are made.
4. Report on the types of musical instruments in a symphony orchestra and how each is played.
5. Report on the methods of reproducing sounds mechanically.
6. Report on the methods of improving the acoustics of a room.
7. Report on how phonograph records are made and played.
8. Test your own hearing.
9. Show how to use a stethoscope.
10. Report on what large cities are doing to reduce noises.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: vibration, compression, rarefaction, percussion, pitch, interval, fundamental, sound wave, echo, timbre, musical scale, wave length, discord, octave, overtone, even-tempered scale?
2. What do we mean by "popular" music? Would you rather listen to "popular" music or to a symphony orchestra? Give the reason for your answer.
3. Is poor timing more noticeable in an orchestra or in a football team? Why?
4. What type of music is common in your community? To what kind of radio and television programs do you listen?
5. What are some of the problems that remain to be solved in perfecting the mechanical reproduction of sounds?
6. How are rooms and buildings soundproofed?
7. How have these inventions helped man: dictaphone, tuning fork, hearing aid?
8. Can people get used to noise? Can you study better when the radio is playing?
9. Why does a person's voice sound differently on the telephone than when heard in person?
10. Why is it more difficult to learn to play the violin than the piano, assuming both instruments are well played?

The old

MAN HAS ALWAYS PRODUCED SOUNDS, AND HAS LEARNED TO make them in many different ways. He has found some of these sounds pleasing and others displeasing. The pleasing ones he called musical, and he developed instruments to produce them. As his knowledge increased, musical instruments became more complex and more difficult to play. The discovery of the nature of overtones helped in understanding the construction and playing of musical instruments.

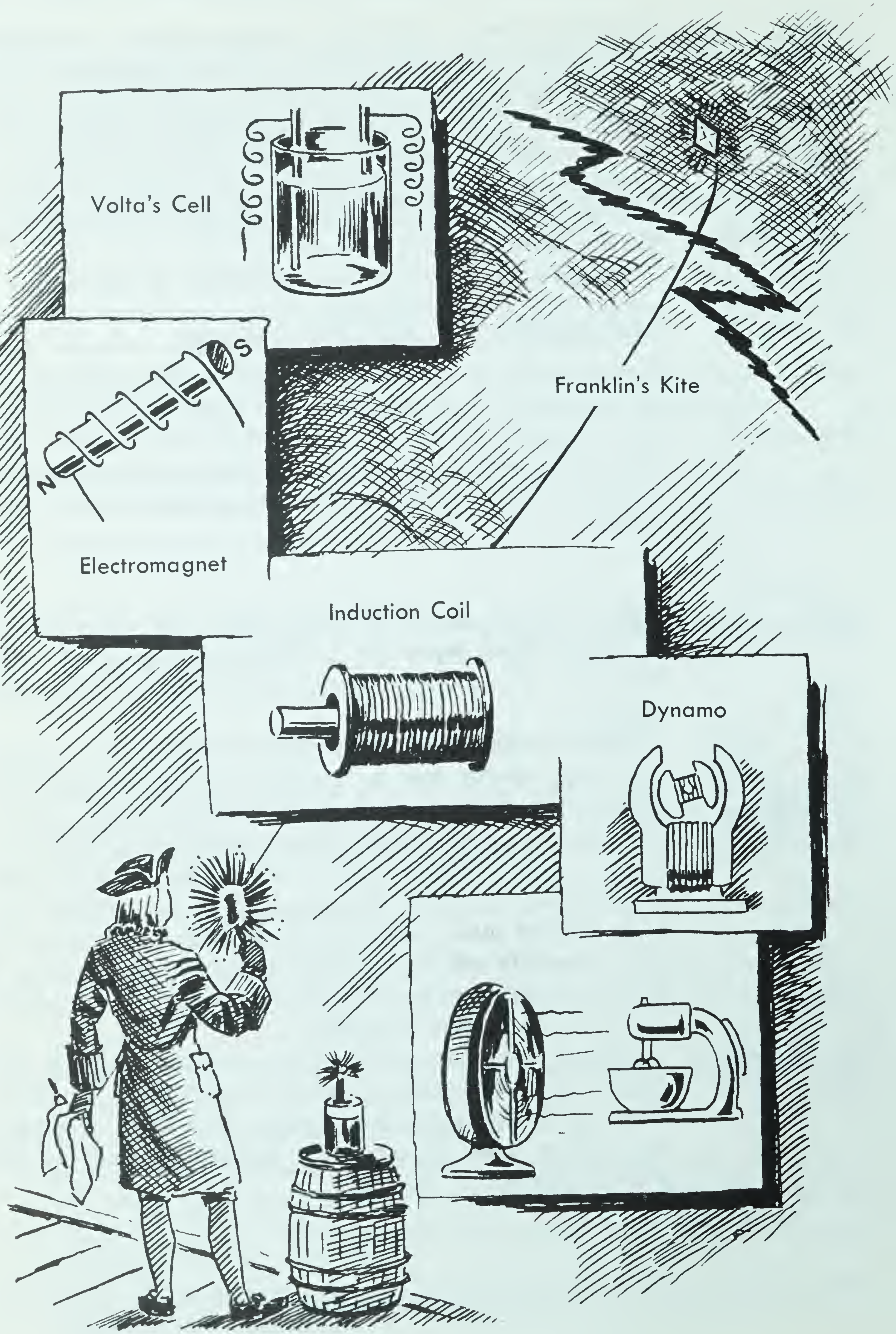
Scientists have always been interested in the nature of sound. They experimented for many years before they found that sound waves would not pass through a vacuum. Some form of matter is needed to carry them. This paved the way for inventions which amplified sound, and also for determining how unwanted sounds can be reduced. When scientists learned that sound waves can actually be photographed, ways were sought to improve the mechanical reproduction of sound waves.

The new

THERE IS STILL MUCH TO LEARN ABOUT THE ACOUSTICS OF buildings, about improving the distribution of sound within them, and also about preventing the entrance of noises from outside.

There is considerable opportunity to improve the methods of storing sounds and to reproduce sounds mechanically. While phonographs have been improved gradually, there is still need for better reproduction of sounds of high pitch and complex musical sounds. Sounds now can be stored on plastic tapes instead of records. The tapes can be run through a machine and the stored sound waves reproduced. These can be used repeatedly without changing the quality of the sound. It is also possible to erase the recorded sound and then use the same tape for another recording.

Modern electronics manufacturers are now producing high fidelity sound equipment capable of reproducing sounds almost exactly identical to the originals. Such "hi-fi" recordings are used in radio and television transmission and in home sound reproduction systems.


Volta's Cell
Franklin's Kite
Electromagnet
Induction Coil
Dynamo

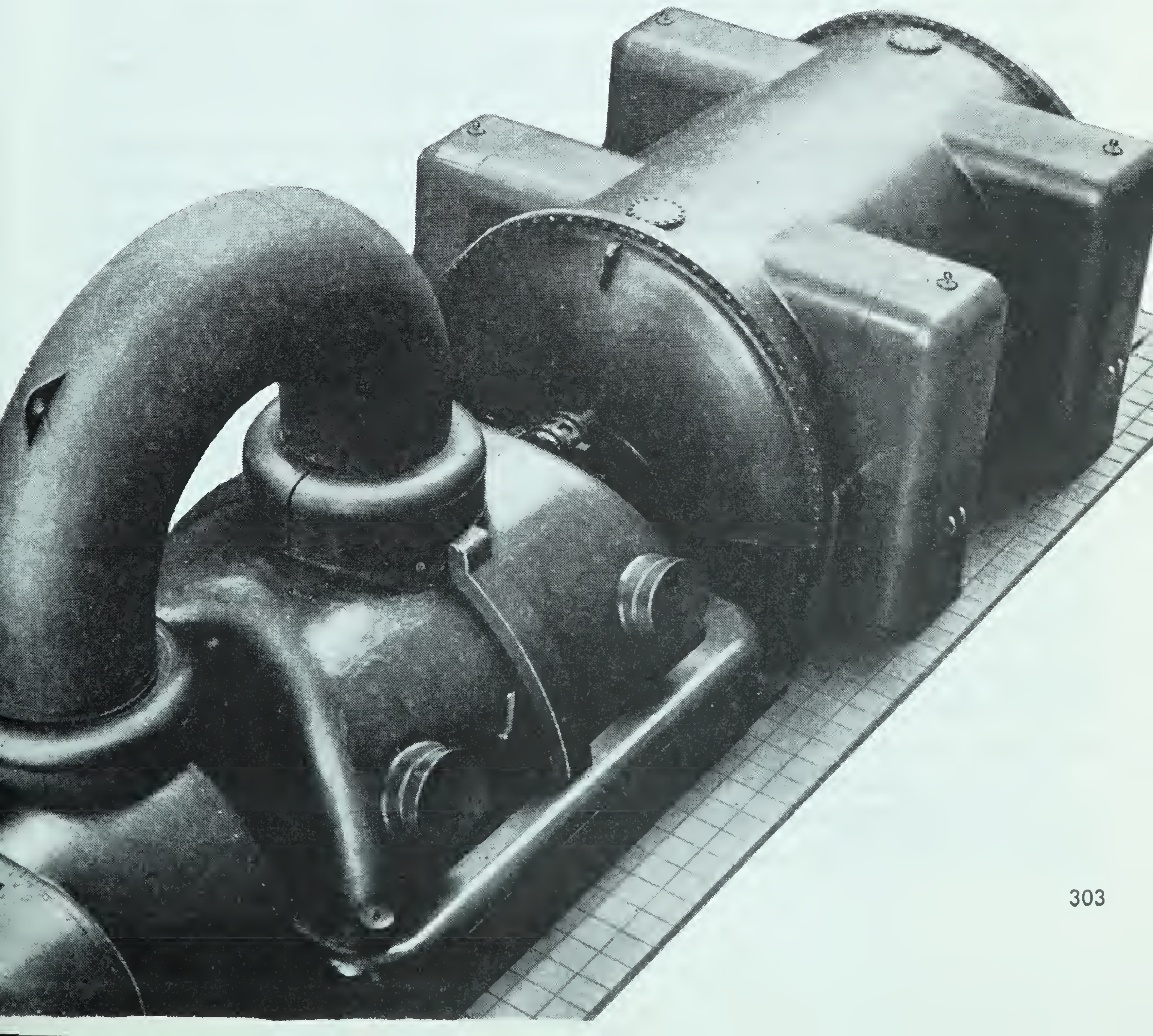
UNIT 11

How has man learned to use electricity and magnetism?

DISCOVERY AND PROGRESS

RECORDS show that man was interested in magnetism from the earliest times. Many legends have come down to us about magnets and magnetism, but they are, of course, completely without scientific evidence.

One legend is about the shepherd, Magnes, who had tacks in his sandals and an iron tip on his staff. One day when he was on Mount Ida in Greece, he was so strongly drawn to the earth



that he could hardly pull himself away. In digging to find the cause, he discovered a wonderful new stone which drew iron to it. Today we know that the stone must have been *magnetite*.

Many methods of making and storing electric charges were discovered during the 18th Century. One of the first was the friction machine. Another was the Leyden jar for storing an electric charge. Benjamin Franklin discovered in 1752 that lightning and electricity were the same.

The electricity, which was known up to this time, was what we call *static electricity*. Little use could be made of it because it was difficult to produce in large quantities. *Current electricity* was discovered in 1780 by Galvani.

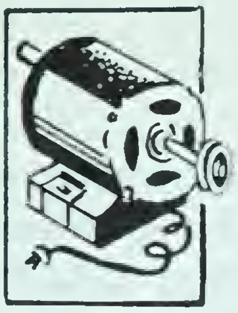
The first electric cell was made in 1800 by the Italian scientist, Volta. This proved that chemical energy could be changed to electrical energy, and led to the beginning of electroplating. Sir Humphry Davy used 2,000 of these cells to supply the first arc light. The first storage battery was made in 1803, but the first one like ours today was not made until 1859.

By 1730, scientists had noticed a close connection between electricity and magnetism. It was not until 1819, however, that Hans Christian Oersted (*ur*-sted) of Denmark found that if a wire carrying an electric current was near a compass, the needle would swing around until it stood at right angles to the wire. When the current was shut off, the needle would swing back to its north and south position again. He had discovered the action of an electric current on a magnet.

Soon after this experiment, many startling things were discovered. Ampere (*ahm*-pair), the French physicist, found that two wires attracted each other if they were close together and a current passed through them in the same direction. But if he sent the current in one wire opposite to that in the other, they repelled each other. Later he demonstrated the principle of the electromagnet. He did this by making magnets out of steel needles by putting them in a coil of wire which was conducting a current. The first powerful electromagnet was made by Joseph Henry in 1829. Today we use electromagnets in electric bells, motors and dynamos, telephones, and telegraphs, and as hoists for heavy lifting.

Michael Faraday worked for seven years on one idea. He said that if an electric current affects a magnet and produces magnetism, he should be able to do something with a magnet to make it produce a current. He found that when he pushed a bar magnet into a hollow coil of wire, he got a current of electricity in the coil. This is the basic principle of the dynamo and motor. By 1839 he had built a small dynamo, which changed mechanical energy into electrical energy.

Dynamos produce most of the electric energy which we use today. Motors are the essential part of many household electrical devices—such as vacuum cleaners, fans, mixers—as well as many machines used in industry.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. In what ways can we produce electric energy? **2.** How do we produce electric energy for a flashlight? **3.** In what ways are electrical pressure and water pressure alike? Unlike? **4.** What is electroplating? **5.** How is electric energy changed to chemical energy? **6.** What are the general properties of magnets? **7.** How does the magnetic field around a magnet differ from the field around a wire conducting a current? **8.** How is an electromagnet made? **9.** What makes an electric bell ring? **10.** What causes the armature of a motor to rotate?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

alternating current current which flows back and forth in a circuit, constantly and rapidly changing its direction.

ampere . . . . (*am*-peer), the unit of rate of flow of an electric current.

circuit . . . . the complete path through which the current flows.

conductor . . . . . . any substance that easily carries an electric current.

direct current . . . current which flows through a circuit in one direction only.

electric current . . flow of electrons along a conductor.

electromagnet . . . a soft iron core with a coil of insulated wire around it. When an electric current passes through the wire, the core becomes a temporary magnet.

ohm . . . . (rhymes with *home*), the unit of electrical resistance.

parallel circuit . . . a circuit in which different quantities of current can flow through the different parts of the circuit.

resistance . . . . . . the opposition of a substance to an electric current passing through it.

series circuit . . . . a circuit in which all the current flows through all parts of the circuit.

static electricity . . electric charges that are not flowing.

volt . . . . the unit of electrical pressure (electromotive force).

A How do friction and chemical action produce electricity?

Electricity is a form of energy. Light, heat, sound, and chemical action are forms of energy which you have already studied. You have also learned that it is possible to change energy from one form to another.

There are only a few natural sources of electric energy. One is lightning. The total available energy of lightning is small and lightning is too infrequent to be of practical use. Another is from animals such as the electric eel. Here again we have a useless natural source of electric energy.

The most important ways of producing electric energy are by: (1) friction; (2) chemical action; and (3) the use of magnets.

Static electricity is produced by friction. In cool dry weather, if you stroke the back of a cat you can hear the fur crackle. Have you ever rubbed your shoes on a rug and felt a shock when you touched something made of metal? Or you may have used a rubber comb on your hair and found that the comb became electrified. It would pick up small bits of paper.

You will find by rubbing certain substances that they attract other light objects to them. We say such substances are *electrified*. Because the electric charge is not flowing, it is called ***static electricity.***

DEMONSTRATION

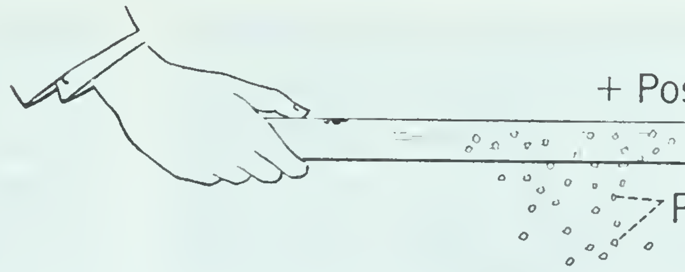
(A) Rub the barrel (lower part) of a fountain pen briskly on your coat sleeve. Try picking up pieces of paper with it. (B) Rub a comb with dry flannel. Will it attract small pieces of paper or cork? Hold the freshly-rubbed comb near a metal conductor, such as a water pipe. What is the tiny spark? (C) Rub a piece of sealing wax with a piece of dry flannel. Result?

What causes the crackling noise when you rub a cat's back with your hand, or when you draw a warm dry comb through your hair?

These articles, when rubbed, become *negatively charged.* (D) Now rub a dry glass rod with a silk handkerchief. Try picking up pieces of paper as before. The glass rod is said to be *positively charged.*

Fig. 11-1. Some flashes of lightning may represent over 100,000,000 volts. Since these flashes last only a short time, the total energy is not very great.

Fig. 11-2. When you rub a glass rod with silk, the glass becomes charged with positive electricity.



The electron theory states that the flow of electrons produces an electric current. You know that all matter is composed of small particles called *atoms.* All the protons in the nucleus of the atom carry a *positive electrical charge,* while all the electrons carry a *negative electrical charge.* The electrons revolve around the nucleus of the atom in regular orbits, somewhat as the planets revolve around the sun.

In the demonstration just performed, some of the negatively charged electrons of the glass rod were rubbed off the rod and became attached to the handkerchief. The rod was then *positively charged* because it contained more protons than electrons. The silk handkerchief was *negatively charged* because it contained more electrons than protons.

If electrons leave an object, the object has a positive charge. The object to which the electrons go will then have more electrons than protons and be negatively charged.

Now let us connect a negatively charged body to a positively charged body with a good conductor of electricity, such as a copper wire. The electrons will flow from the negatively charged body through the conductor to the positively charged body. This flow will continue until the charges on the two bodies are equal. Scientists believe that the electrons move from atom to atom in the conductor until they reach the positively charged body. This movement of electrons from atom to atom is an *electric current.*

We can produce electric energy in cells by chemical action. Let us put two different metals in a salt, soda, or acid solution. Then let us connect the ends of the metals with a wire. What happens? An electric current will flow through the wire. It is easy to make an electric cell with common materials.

DEMONSTRATION

Get a sheet of zinc about 4 inches long and 3 inches wide, and a piece of copper the same size (or a rod of both). Punch a hole in each metal strip near the top and fasten in each hole a piece of copper wire about 3 feet long. Connect the wire from the zinc strip to the negative ter-

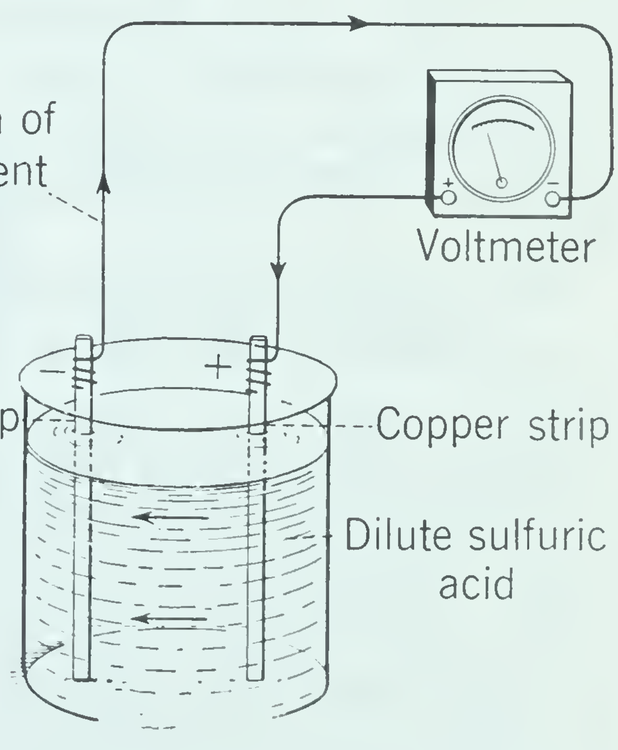


Fig. 11-3. In an electric cell, electric energy is produced by the chemical action of the dilute sulfuric acid on zinc.

minal of a voltmeter that will measure low voltages. Attach the wire from the copper strip to the positive terminal of the voltmeter (see Fig. 11-3). Put the strips in a small glass battery jar. Pour water into the jar until it is about two-thirds full. Add concentrated sulfuric acid, a little at a time, until bubbles appear on the plates. See that the metal strips do not come in contact with one another. Will the cell furnish enough current to ring an electric bell? Try it. What is the reading of the voltmeter? What are the bubbles?

Put a few pieces of zinc in a test tube and add a few drops of dilute sulfuric acid. Try to ignite the escaping gas. Result? What is the gas? Try the acid on copper.

When the cell is in use, hydrogen bubbles soon collect on the copper plate so thickly that they interfere with the passage of the current. Therefore, this type of cell is of little practical use.

Electricity is produced by the chemical action of the acid on zinc. Zinc acts as a sort of fuel and you must replace it from time to time. The acid acts on the zinc and produces: (1) *zinc sulfate* which dissolves in the fluid; and (2) *hydrogen* which collects on the copper plate.

When the zinc atoms dissolve, some of their electrons are left on the zinc plate. As more zinc dissolves, more electrons collect on the zinc plate. If this chemical action goes on for some time, a large number of electrons collects on the zinc plate. The copper, on the other hand, does not dissolve. Soon the electrons on the zinc plate repel each other and some are forced through a wire connecting the two metals. As with the charged bodies, this flow of electrons is called an *electric current.*

The current flows from the *negative* (−) zinc plate, which has more electrons, to the *positive* (+) copper plate, which has less electrons. The flow of electrons is the electric current. The current flow on the outside of the cell is from the negative to positive plates. The electrons will continue to flow through the outer circuit as long as there is a chemical action within the cell.

The current flows through a circuit of liquids, plates, and wires. A ***circuit*** is the complete path through which the current flows. Touching the ends of the wire together is called *making the cir-*

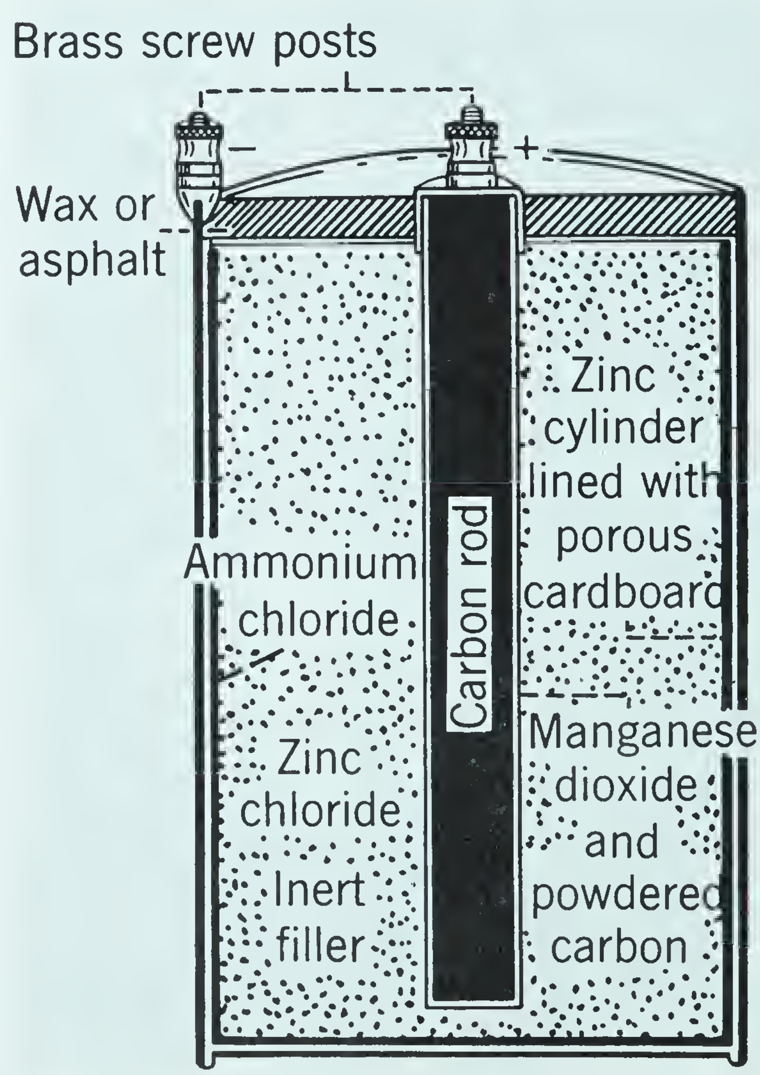


Fig. 11-4. This is a sectional view of a dry cell. What is the negative pole and what is the positive pole?

cuit; separating them is called *breaking the circuit.*

The cell that we have just studied is called a ***voltaic*** (vol-*tay*-ick) ***cell.*** Some people might call it a battery, but this is not accurate. Properly speaking, an electric battery is made of two or more electric cells connected together.

Dry cells differ from wet cells. The simple voltaic cell is called a ***wet cell*** because it has in it a liquid (sulfuric acid). A ***dry cell*** differs from this in that the materials in it are in the form of a damp paste.

The common dry cell has a zinc can which is the *negative pole.* The *positive pole* is the rod of carbon in the middle. Chemicals in the cell dissolve the zinc can just as the sulfuric acid attacks the zinc in a wet cell. The black manganese dioxide around the carbon rod helps to get rid of the bubbles of hydrogen which form on the carbon rod. A thin layer of wax or asphalt is used at the top to seal in the moisture. (See Fig. 11-4.)

DEMONSTRATION

Connect a worn out dry cell to an electric bell. Result? Explain. Punch a number of holes through the zinc can with a nail. Set the cell in a jar of water for a few hours. Now try to ring a bell with it. Result? Explain. Are "dry" cells really dry cells? What sort of cells studied are most convenient for ringing electric bells?

After a while, a dry cell gets weaker and weaker because the chemicals are being used up. If you put it aside for a time, it will produce electric energy again but soon will become "dead."

Recently, scientists have discovered a battery that is powered by sunlight. This ***solar battery*** consists of many plates of the element silicon in a very pure form. When these are exposed to sunlight, an electric current is generated. It requires about one square yard of silicon plates to produce 100 watts of electrical power.

Although the solar battery is not yet in common use, its future looks bright. It requires no fuel and there are no moving parts to wear out.

REVIEW QUESTIONS

1. What is an electric current? **2.** What is static electricity? **3.** What materials are used to make a voltaic cell? **4.** What are the materials used in making a dry cell? **5.** How is electricity produced in a cell? **6.** Why should the date of manufacture be marked on cells? **7.** How do dry cells differ from wet cells? **8.** In what direction does the electric current flow? **9.** What material is used in the solar battery?

B What causes a current to flow through a circuit?

It takes an electrical force to cause a current to flow through a wire. If you want to force water through a pipe, you must apply force to the water. The quantity of water flowing through a pipe depends on the amount of force and size of the pipe. A small pipe will have more resistance and will carry less water than a large one, providing the

pressures in the two pipes are the same.

The amount of water flowing in a pipe is proportional to the pressure; the greater the pressure, the greater the flow. The diameter of the pipe also determines the rate of flow; the larger the pipe, the greater the flow. We measure the *quantity* of water flowing in gallons per minute and the *pressure* in pounds per square inch.

Electricity does not flow through wire exactly as water flows through a pipe. But in order to understand electricity and how it affects matter, we will use the same general terms. Electrical pressure has a different meaning from water pressure. It refers to the *electromotive force* pushing electrons through the conductor and not to the force per unit of area.

The unit for measuring electromotive force (pressure) is the *volt.* For the rate of flow of current it is the *ampere* (*am*-peer). For resistance (the opposition to current flow) the unit used is the *ohm.*

In 1826, Georg Simon Ohm discovered how electrical pressure, rate of flow of current, and resistance are mathematically related to each other. The relationship, called *Ohm's Law,* can be expressed in this way:

$$\frac{\textit{pressure}}{\textit{resistance}} = \textit{quantity of current}$$

or, in electrical units:

$$\frac{\textit{volts}}{\textit{ohms}} = \textit{amperes}$$

You can increase the quantity of current flowing in a circuit by increasing the voltage or by decreasing the resistance, or by doing both.

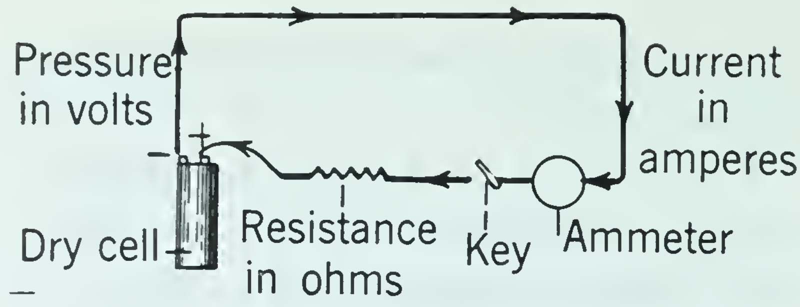


Fig. 11-5. The dry cell provides the electrical pressure to force a current through the resistance of the wire.

A dry cell furnishes the electrical pressure to force the current through the resistance of the wire. Look at Fig. 11-5 which shows an electric circuit. The dry cell provides the pressure. The *ammeter* (*am*-mee-ter) is an instrument which measures the rate of flow of the current. The key is introduced to stop or to start the current flow in the circuit.

If the resistance of the wire is 1.5 ohms and the pressure of the dry cell is 1.5 volts, 1 ampere of current will flow through the circuit when you close the key. This is how we solve the problem:

$$\frac{\textit{volts}}{\textit{ohms}} = \textit{amperes}$$

or

$$\frac{1.5}{1.5} = 1 \textit{ ampere}$$

What current will flow through the circuit if you use two dry cells and increase the pressure to 3 volts ($1.5 + 1.5 = 3$)? Again, using the same formula:

$$\frac{\textit{volts}}{\textit{ohms}} = \frac{3}{1.5} = 2 \textit{ amperes}$$

What pressure is needed to cause a current of 3 amperes to flow through a resistance of 2 ohms?

$$\frac{volts}{ohms} = amperes$$

then, $$\frac{volts}{2} = 3$$

Solving this equation, we find that the pressure needed is 6 volts.

REVIEW QUESTIONS

1. What causes water to flow through a pipe? **2.** What determines how much water flows through a pipe? **3.** What causes electricity to flow through a wire? **4.** What are the units of electrical pressure, resistance, and quantity of current? **5.** In what two ways can you increase the quantity of current which flows in a circuit? Decrease it? **6.** How many amperes will flow through a circuit of 3 ohms resistance if the pressure is 6 volts?

C What are series and parallel circuits?

Series circuits are those in which the current flows through each appliance in turn. A *circuit* is the complete path through which the current flows. All current in a *series* circuit flows through all parts of the circuit. In some sets of Christmas tree lights all the lamps are connected in series. In this kind of set, all the current flows through each lamp in turn. If you break a series circuit at any point, there will be no current flowing in any part of the circuit. That is why all

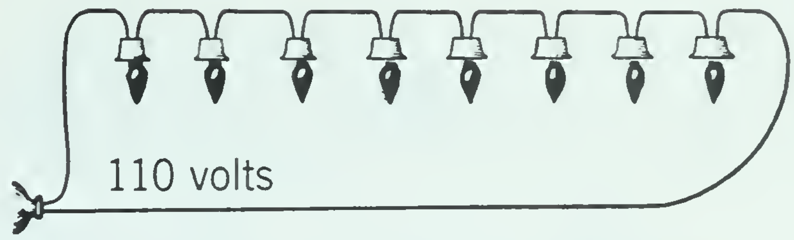


Fig. 11-6. Small lamps, like Christmas tree lights, are connected in series to increase the resistance.

lights go out in the string when one burns out.

Series wiring increases the resistance of the circuit. This means that less current can flow in the circuit. Most home appliances are made to operate at 110 to 120 volts. This means they have enough resistance to prevent too large a flow of current. The total resistance of a string of Christmas tree lights in series will be about as much as one average incandescent lamp.

DEMONSTRATION

Connect 110-volt lamps and keys as shown in Fig. 11-7, with key 1 closed. Result? Next, connect two lamps connected in series by leaving keys 1 and 3 open and key 2 closed. Result? Two lamps connected in series have twice as much resistance as one lamp. Do two lamps burn as brightly as one? Next, connect three lamps in series by leaving keys 1 and 2 open and key 3 closed. Result? Unscrew one bulb. What happens? Is it advisable to connect three such lamps in series? Why? Explain what happens when the three keys are closed.

Electricians do not connect lamps in your home in series. The reason is that the increase in resistance would cause a decrease in the rate of flow of current. You can see from the demonstration that the lamps are not bright

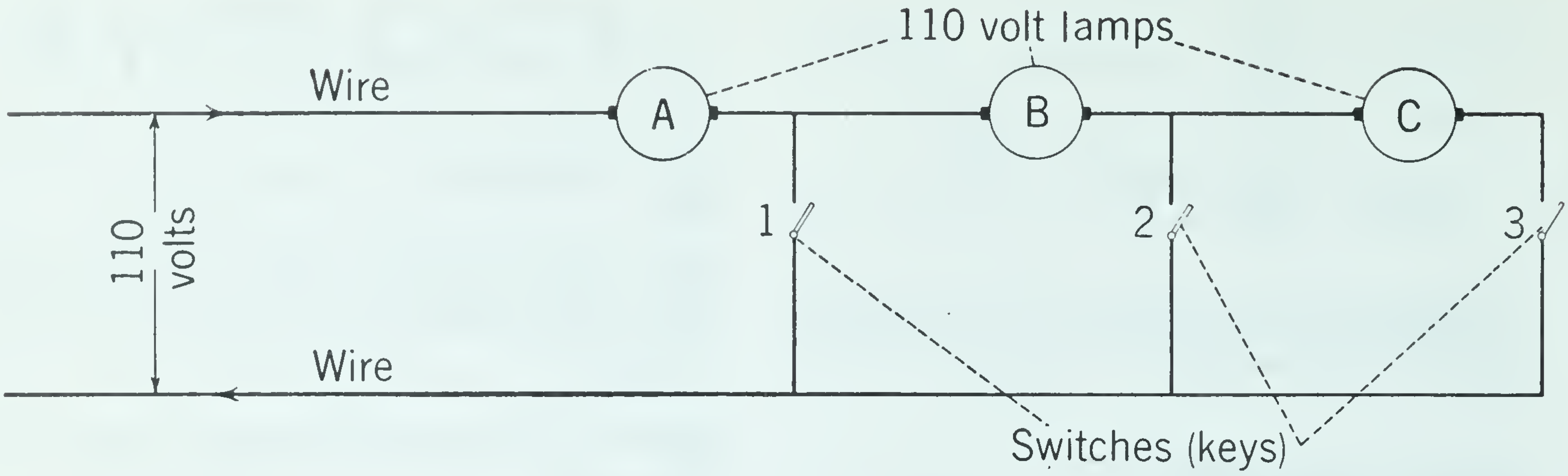


Fig. 11-7. Connecting lamps in series increases the total resistance and decreases the rate of flow of current.

enough to give much light when more than one is used in a series circuit.

The electric energy delivered to your home is kept at a constant voltage. The only way more current can be forced through a circuit when the resistance is increased is by increasing the voltage.

DEMONSTRATION

Remove the lamp and cells from a flashlight. Wind one end of a bare copper wire tightly around the metal part of the lamp. Connect the other end of this wire to the center pole of a dry cell. Connect one end of another bare wire to the zinc pole of the dry cell and touch its other end to the contact point at the base of the lamp. This forms a complete circuit. (See Fig. 11-8.) How brightly does the lamp glow? Now put two cells in the circuit so that the center rod of one touches the zinc bottom of the other. Connect the wires as before. Result? Conclusion?

In a flashlight, one cell will produce enough pressure to light one 1.5-volt lamp. For a 3-volt lamp, how many cells in series are needed? How many cells are needed for a 6-volt lamp? What would happen if you used a 3-volt lamp with a 6-volt battery?

Electrical quantities are measurable. If you connect a voltmeter to the poles of a new dry cell, the reading will be approximately 1.5 volts. A dry cell then can produce a difference of pressure of 1.5 volts between the two poles of the cell. If you connect an ammeter to the poles of a new dry cell, the reading will be from 20 to 30 amperes. Be sure the ammeter you use has a scale reading of at least 30 amperes.

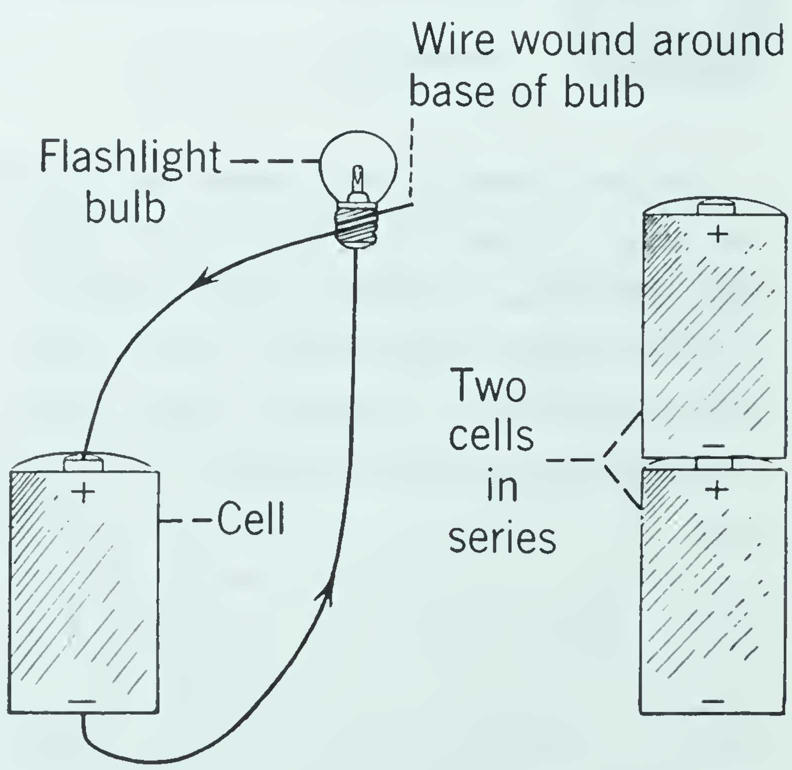


Fig. 11-8. The cells in a flashlight are connected in series to increase the voltage.

DEMONSTRATION

Connect one dry cell, a key, an ammeter, and some resistance wire as shown in the diagram in Fig. 11-9. Connect the voltmeter across the poles of the cell. When connecting electric meters in a circuit, always be sure to connect their positive terminals to the positive pole of the cell or battery (and the negative terminal with the negative pole). The voltmeter measures the total electrical pressure the cell produces. The voltmeter is a high-resistance instrument and is always connected so the current in the circuit does not need to flow through it. The ammeter is a low-resistance instrument and is connected so that the current in the circuit flows through it. Because its resistance is so low, it does not materially affect the flow of the current.

Close the key. What is the ammeter reading? Reduce the length of the resistance wire in the circuit by one-half. How is the ammeter reading affected? Then reduce the length of the wire in the circuit to one-fourth its original length. How does decreasing the length of the wire affect the resistance of the circuit?

How does it affect the amperes flowing in the circuit? Connect two cells in the circuit. Connect the zinc pole of one cell to the carbon pole of the other cell. Two dry cells connected in this way will produce a pressure of approximately three volts. Close the key. How is the ammeter reading affected? What are the two ways in which the rate of current flowing in a circuit can be increased?

In a complete circuit the current must return to the point from which it started. The path outside the cell is the *external circuit* and the path on the inside is the *internal circuit*. We can increase the current flowing in an ex-

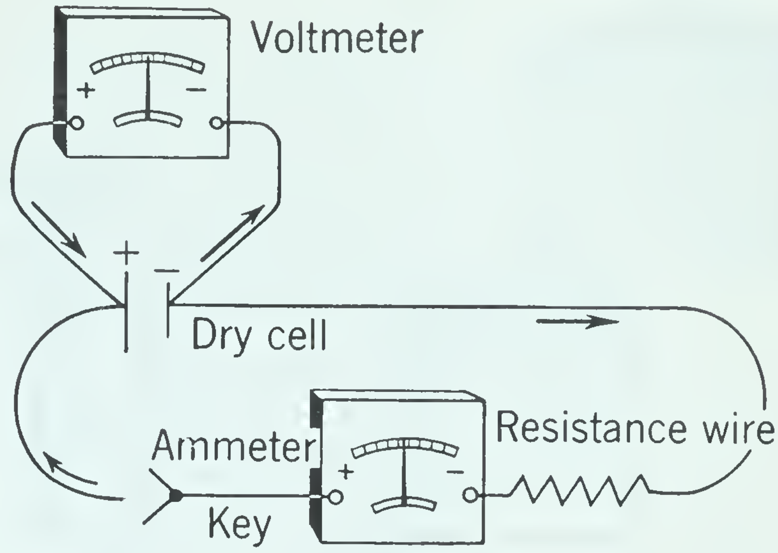


Fig. 11-9. The current in a circuit may be increased by increasing the voltage and decreasing the resistance.

ternal circuit by increasing the voltage or by decreasing the resistance.

Cells are connected in series to increase the pressure. Let us try this experiment:

DEMONSTRATION

Join two or three dry cells by connecting the zinc of one cell with the carbon of the next cell, and so on. The cells are now said to be joined in series. (See Fig. 11-10.) Test the pressure or voltage of the current by using a voltmeter. What is the reading of one cell? Of two cells in series? Of three cells?

Joining three cells in series results in increasing the electrical pressure or voltage to three times that of a single cell. Higher voltage forces electricity through longer wires, such as those leading to the bells in a home and the long fine coils used in bells.

The resistance of a wire increases with length. It can be great enough to prevent much current from flowing through it if the pressure is low. Cells

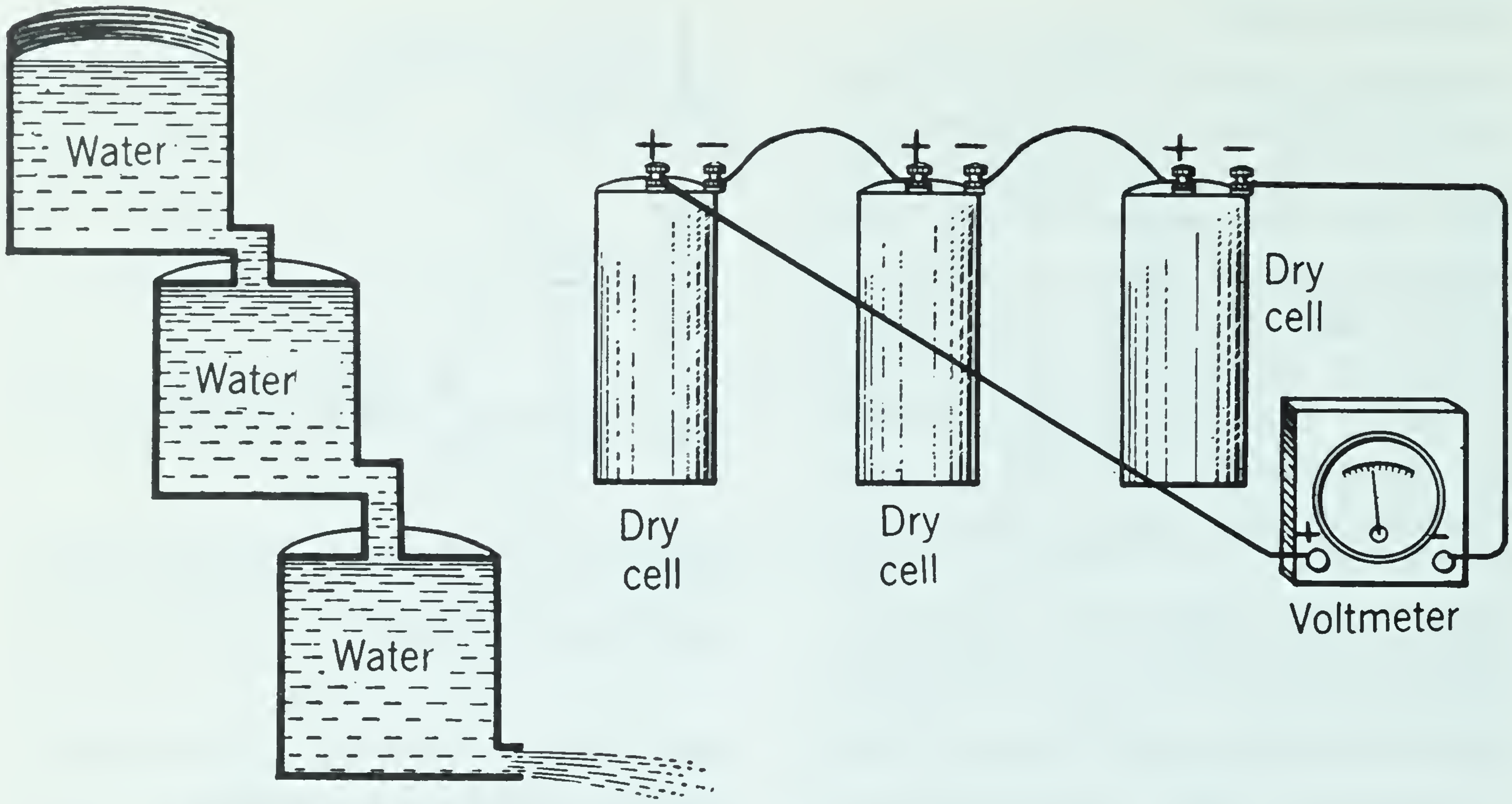


Fig. 11-10. Connecting cells in series increases the voltage. How does this compare with the water pressure in the bottom tank on the left?

are connected in series to overcome high resistance, and to increase the voltage.

Cells are connected in parallel to increase the current, or amperage. This is done when little pressure is needed to force the current through the circuit. When connected in series, all the current must flow through all the cells. This arrangement is used to get a higher voltage when the resistance in the circuit is higher.

In ***parallel*** connection, the current from one cell does not flow through the others. Thus the current in the external circuit is equal to the sum of the currents from the parallel cells. But the voltage of the cells in parallel is that of a single cell.

Cells in parallel are used when the

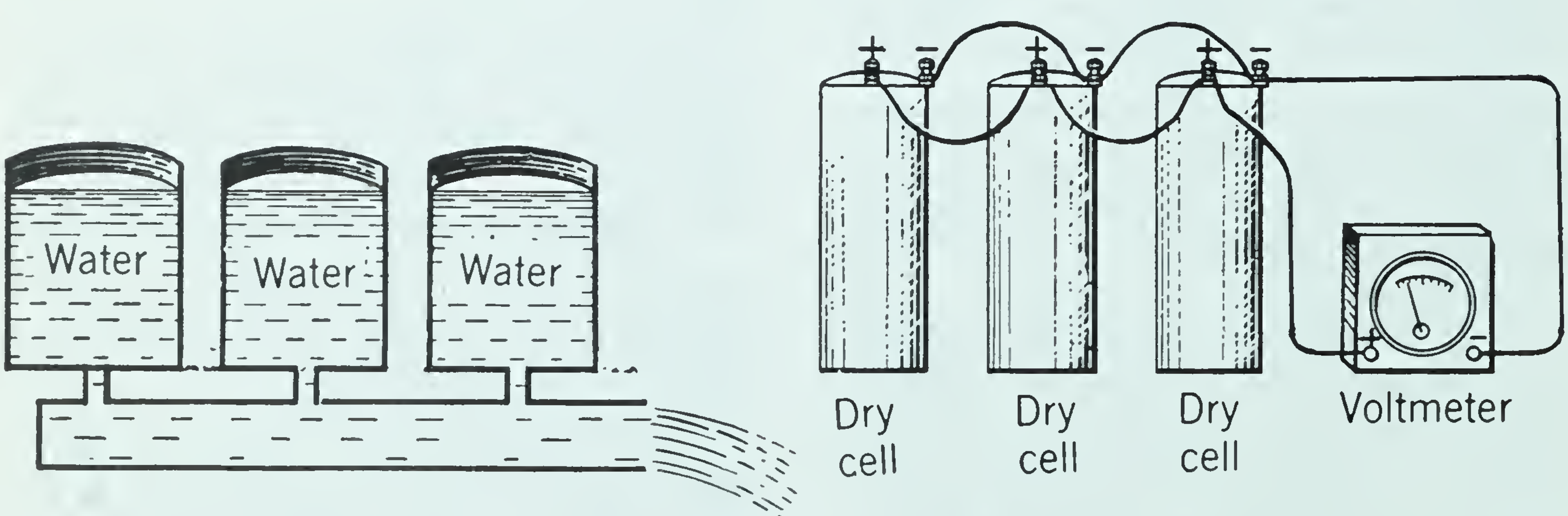


Fig. 11-11. The pressure from the three tanks of water is the same as from one. In the same way, in parallel circuits, the current from one cell does not flow through the others.

resistance of the external circuit is small. If the external resistance is high, the cells are connected in series.

DEMONSTRATION

Join the same cells together by connecting all the zinc caps to one wire, and all the carbon rods to another wire. The cells are now joined in parallel (see Fig. 11-11). What is the voltage from all three cells in parallel?

The diagram in Fig. 11-11 shows the comparison with water pressure. Note that the three tanks are at the same level; hence there is no greater pressure than from a single tank. The water will flow out more rapidly than it did when one tank was put above the other. Why? Cells joined in parallel produce a current having the voltage of one cell and amperage depending on the number of cells joined.

If several appliances are operated from the same voltage, they must be connected in such a way that the total resistance will be decreased. When lamps are connected in parallel, one lamp can "burn out" without affecting the others. This is also the case with Christmas tree lamps when they are connected in parallel. The voltage of each lamp is 110 to 120 volts. In a parallel circuit, the current can divide. One part of the current can go through one appliance and the remainder of the current through others.

If two wires of the same size are connected in parallel, the resistance of the two wires is one-half as much as that of one wire. The two wires wound together make one wire twice as large as either wire and of the same length. The resistance of two lamps in parallel is one-half as much as that of one lamp. Then twice as much current can flow through the circuit leading to the lamps. The current divides on reaching the lamps, one-half going through each lamp. In this way each lamp gets as much current as it needs, and just as much as one lamp does if connected in the circuit.

DEMONSTRATION

Connect four 40-watt, 110-volt lamps in parallel as in Fig. 11-12. Insert the wall plug and close the key with only one lamp in circuit. Result? Next, put a second lamp in the circuit. Result? Two lamps in parallel have only one-half as much

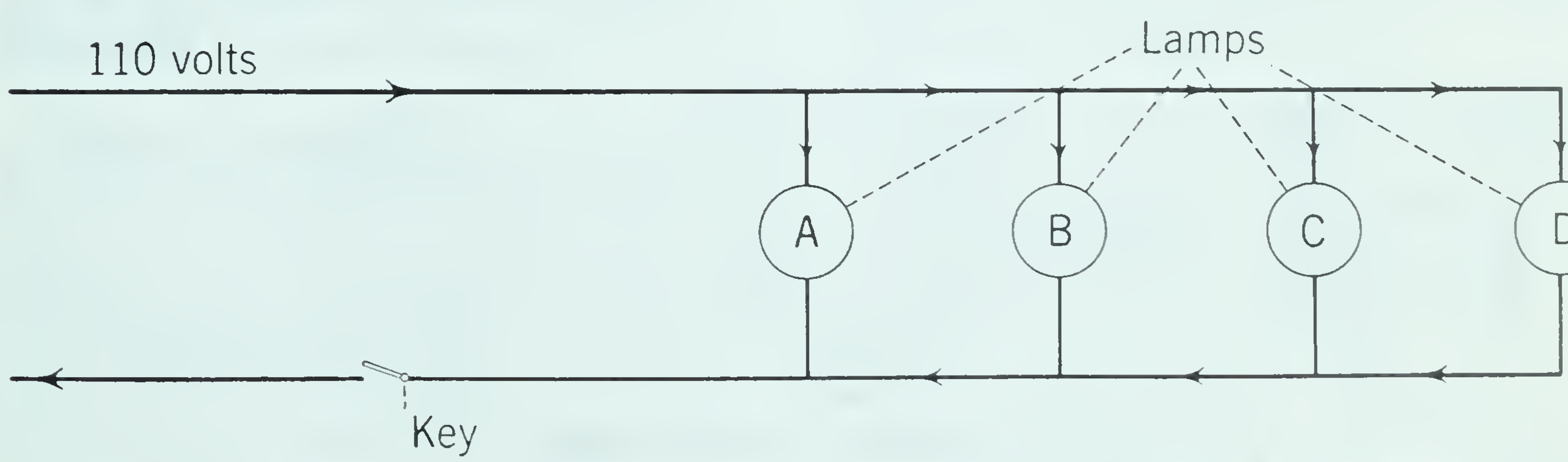


Fig. 11-12. Connecting lamps in parallel decreases the total resistance and increases the total number of amperes flowing.

resistance as one lamp. Then, put a third lamp in the circuit. Result? Finally, put a fourth lamp in the circuit. Result? What happens when one of the lamps is removed from the circuit?

As each lamp or appliance is added to a parallel circuit, the total resistance is decreased and the total number of amperes flowing is increased. The current divides, each appliance thus getting the necessary current. Electric irons with low resistance get more current than a small lamp which has high resistance.

Fuse plugs protect wires from getting overheated. A short circuit cuts out the normal resistance in a circuit. This produces a large amount of heat in a short time, because of the increased flow of current. The wires in the walls and ceilings get overheated and may set the building on fire. Unless a short circuit is stopped immediately, serious damage results.

How does a fuse plug give this protection?

DEMONSTRATION

Connect in series several dry cells, two large copper wires, a key, and a piece of fine fuse wire about three inches long as shown in the diagram in Fig. 11-13. Fine

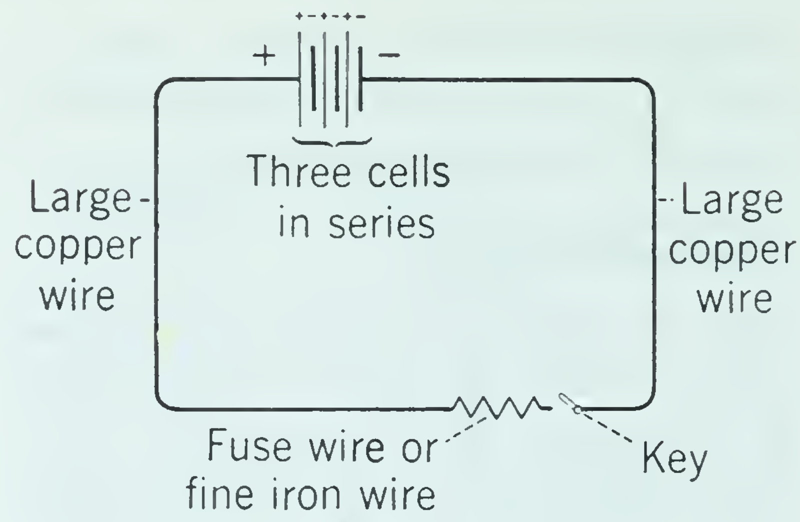


Fig. 11-13. A fuse plug prevents the wiring system from becoming overheated.

iron wire can be substituted for the fuse wire. Close the key. Result? Examine a fuse plug. Where is the metal that acts as the fuse? How could the fuse be repaired if it were melted?

The fuse wire has more resistance than the other wires in a circuit. It also melts at a lower temperature. If too much current flows, the fuse wire melts and breaks the circuit. This stops the flow of current and keeps the wiring system from getting overheated.

Fuse plugs in a house are made to carry 10 or 20, and occasionally, 30 amperes. If more than 10 amperes flow through a ten-ampere fuse, the wire melts and breaks the circuit. The current will not flow through the fuse plug until you replace it with a new one.

In the home, the addition of ap-

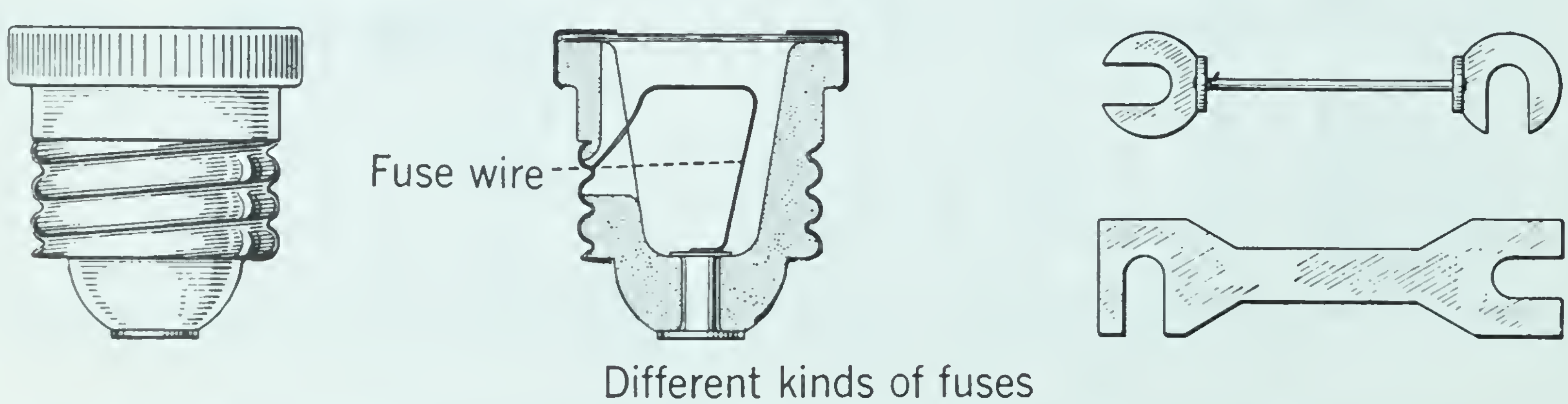


Fig. 11-14. Although there are many different kinds of fuses, they all contain wire or bars which melt at low temperatures.

pliances in parallel increases the rate of flow of current. If enough appliances are added, the total current can exceed the amount the fuse plug is made to conduct without melting. When this amount is exceeded, the fuse melts and the wiring does not overheat.

In some buildings, automatic circuit breakers are used instead of fuses. These work by means of electromagnets which break the circuit when too much current flows. They cost more than ordinary fuses, but they do not need to be replaced every time the circuit is overloaded.

REVIEW QUESTIONS

1. What are the characteristics of a series circuit? **2.** What are the characteristics of a parallel circuit? **3.** Under what conditions are series and parallel circuits used? **4.** How are incandescent lamps usually connected? **5.** What is a short circuit? **6.** What is a fuse plug? What is its purpose? **7.** Why are circuit breakers often used instead of fuse plugs?

D How is electricity distributed and used in our homes?

Electrical energy is delivered to the home at a constant voltage. This is usually 220 volts, although in many areas 120 volts is still used. Look at the wires that lead into your home. Three wires indicate 220 volts, while two wires mean 120 volts. Your electric meter will also be marked according to the voltage coming into it. This pressure is controlled at the central power station.

Alternating current, or A.C., is usually used in the home because it is easily carried over long distances and is satisfactory for different uses. Alternating current flows back and forth in a circuit, constantly and rapidly changing its direction. Very few communities still use *direct current,* or D.C. Direct current is needed, however, for charging batteries, electroplating, and for some types of electromagnets. Alternating current can be changed to direct current by the use of a *rectifier* (*rek*-tih-fy-er). You can see one of these at your local service station where it is used to charge automobile storage batteries. Some toy electric trains use a rectifier to produce direct current.

Many cities require that the electric wires entering a building be enclosed by metal pipes or *conduits* (*kon*-dew-its). These protect people from accidental contact with exposed wires. They also protect the wires from gnawing animals, such as rats and mice. Conduits guard against the possibility of short circuits at the point where the electric wires enter the building.

The electricity entering the home first passes through an electric meter. The meter contains a form of motor whose speed is determined by the quantity of current being used. The greater the quantity of current being used, the greater the speed of rotation.

The meter measures the electrical energy in *kilowatt hours.* The hands on the dials indicate the readings in 10, 100, 1,000, and 10,000 kilowatt hours.

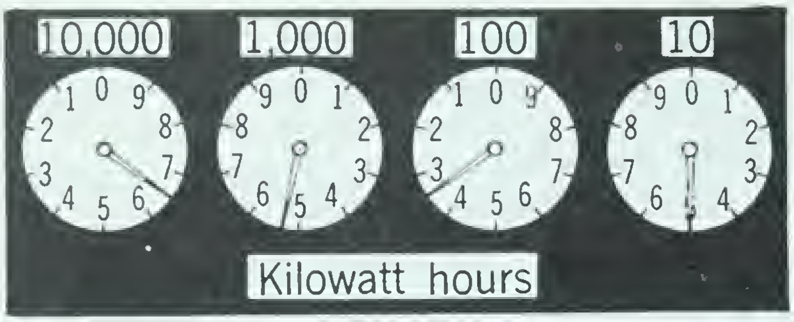


Fig. 11-15. The meter registers the kilowatt hours of electricity used.

You should note that the hands on the dials next to each other move in *opposite directions*. The reading of the meter shown in Fig. 11-15 is 6,535 kilowatt hours.

The electric current flows from the meter to the fuse box. The *fuse box* in your home is wired for at least two separate circuits depending on the appliances used. Each of these circuits contains a fuse. This fuse will vary in capacity depending on the amount of current to be used in the circuit. The master fuses, usually in a separate fuse box, control two or more circuits.

The fuses in most home circuits range from 10 to 20 amperes at a voltage of 110-120. Electric stove circuits are usually 220 volts and require fuses up to 30 amperes capacity.

The electric current from the fuse box flows through the wires in each circuit to the appliances. You will see from the diagram in Fig. 11-16 that the four circuits are connected *in parallel* with each other in the fuse box. Thus you can use any of the circuits connected with the main fuse box. In wiring the separate circuits, large enough wire is used so that the total current flowing in that circuit will not cause overheating.

A burned-out fuse should be replaced with another of the same amperage. The cause of the burning-out should be corrected before you replace the burned-out fuse. Remove the burned-out fuse by turning it, just as you would to remove a lamp from its

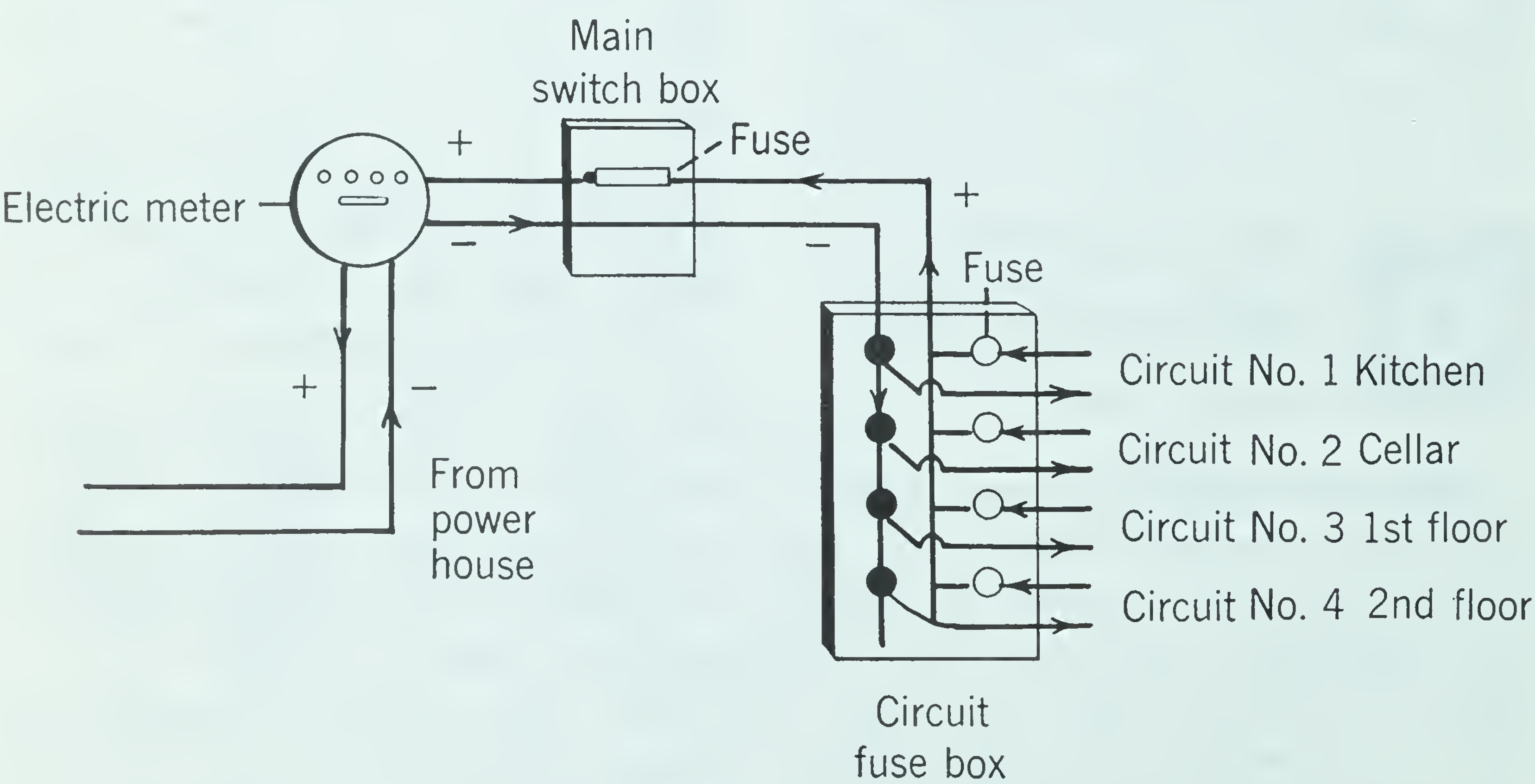


Fig. 11-16. Because modern homes use so much electricity, many circuits are necessary to prevent overloading fuses.

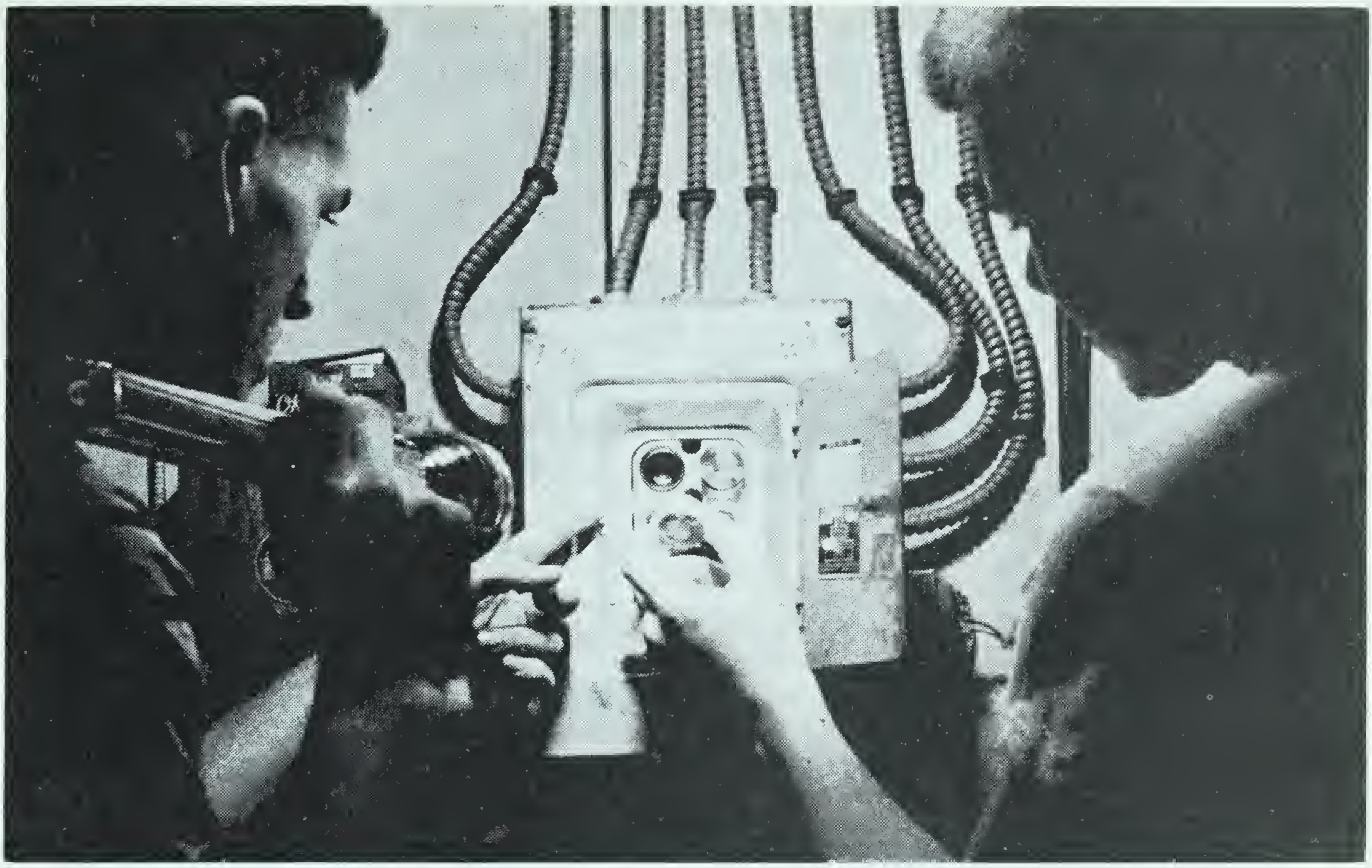


Fig. 11-17. When you replace a burned-out fuse, be sure that the new one is of the same amperage as the old one.

socket. You should first disconnect the circuit to the fuse box by lowering the lever at the upper part of the box, or by pulling out the master fuse block.

Watts are the product of volts and amperes. We know that the current flowing in a circuit is equal to the pressure divided by the resistance, or

$$\frac{\textit{volts}}{\textit{ohms}} = \textit{amperes}$$

A *watt* is the power being used when a current of one ampere is caused to flow by a pressure of one volt. This can be expressed in brief form as: *watts* = *volts* × *amperes*. A watt used continually for one hour is a watt hour. Two watts used for half an hour is also a watt hour. One thousand watt hours is equal to one *kilowatt hour*. We can state this as follows:

$$\textit{kilowatt hours} = \frac{\textit{volts} \times \textit{amperes} \times \textit{hours}}{1{,}000}$$

The appliances in a circuit are connected in parallel. A *parallel circuit* is one in which the same or different quantities of current can flow through the different branches of the circuit. Connecting the appliances in parallel decreases the total resistance as each appliance is added. Thus each appliance can draw as much current as it requires without reducing the current flowing in other circuits. In a parallel circuit, the pressure across the wires is the same for all parts of the circuit. The appliances used for a circuit are made to operate on a certain voltage or pressure. Enough resistance is added to give the desired amperage.

For example, suppose the problem is to have one ampere flow through an appliance when the pressure is 110 volts. What will be the resistance in ohms? Applying the formula, we get

$$\frac{110\ volts}{X\ ohms} = 1\ ampere$$

Then X must be 110 ohms which is the resistance. If the current desired is two amperes, then the resistance is 55 ohms, or

$$\frac{110\ volts}{X\ ohms} = 2\ amperes$$

and

$$X = 55\ ohms$$

If the current desired is .5 ampere, then the resistance must be 220 ohms.

A lamp marked 100 watts will draw approximately .9 ampere on a 110-volt circuit. Knowing that watts = volts × amperes, we can substitute these values and get the answer as follows:

$$100\ watts = 110\ volts \times X\ amperes$$

$$X = .909\ ampere$$

The resistance of this lamp may be calculated from the formula:

$$amperes = \frac{volts}{ohms}$$

or $.909 = \frac{110}{Y}$, *and* $Y = 121$ *ohms.*

You can also calculate the amperes of current flowing through each appliance as follows:

60-watt lamp = 110 volts × .54 ampere
660-watt iron = 110 volts × 6 amperes
550-watt toaster = 110 volts × 5 amperes

The total current used by all the appliances on the circuit illustrated in Fig. 11-18 is 12.4 amperes. The total current of 12.4 amperes in the wires leading to the appliances divides into several paths. Each appliance draws the current indicated in the diagram.

In a parallel circuit the current can divide, with a part of it flowing through each appliance. The appliance with the

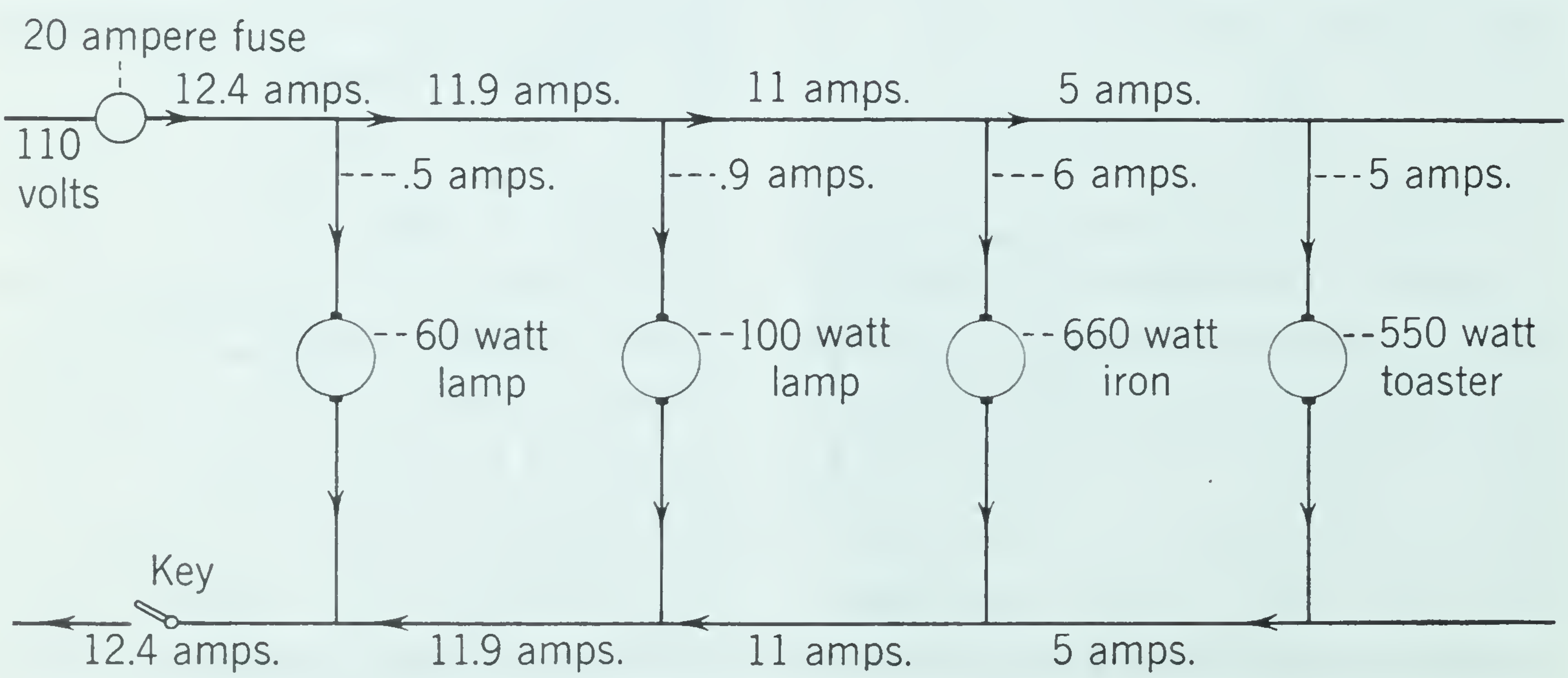


Fig. 11-18. In a parallel circuit, the appliance with the least resistance draws the most current. The 60 watt lamp has the greatest resistance and the 660 watt iron the least.

Fig. 11-19. The modern home uses many electrical appliances. Which of these appliances do you think would use the least current?

least resistance draws the most current. Which appliance in Fig. 11-18 has the greatest resistance? The least?

The cost of electrical energy is based on kilowatt hours. A 100-watt lamp in use for 10 hours will consume 1,000 watt hours of electrical energy, or 1 kilowatt hour. If the cost of electrical energy is 6¢ per kilowatt hour, the total cost of operating the 100-watt lamp for ten hours is 6¢. You can find the cost as follows:

$$\frac{\textit{watts} \times \textit{hours} \times \textit{cost per k.w. hour}}{1{,}000}$$

Or, we can say: kilowatt hours times cost per kilowatt hour. If all the appliances in Fig. 11-18 were used for one hour, the total number of watt hours would be 60 + 100 + 660 + 550, or 1,370 watt hours. This is equal to 1.37 kilowatt hours. At 6¢ per k.w. hour, the total cost of operating the appliances for one hour would be about

Fig. 11-20. Powerful lights, like the ones in this stadium, have made night baseball possible.

8¢. For ten hours it would be about 82¢.

In finding the cost of the electrical energy used in your home for one month, multiply the number of kilowatt hours used for that period by the cost per k.w. hour. The rates are usually given on the bill. The rate is reduced per kilowatt hour as the total number of kilowatt hours used increases. Calculate the rates for each number of k.w. hours by the cost of that number of k.w. hours.

Electric power companies often give special rates when electricity is used for heating hot water in the home. Find out if this applies in your community. Industries also are frequently supplied with power at reduced rates. Is this true in your community?

REVIEW QUESTIONS

1. What are conduits? Why are they used? **2.** Why should you disconnect the switch when you repair any electrical appliance or piece of wiring? **3.** What does the electric meter measure? **4.** What is the purpose of the fuse box? **5.** Why are home appliances connected in parallel? **6.** What is the advantage of having more than one circuit leading from the fuse box? **7.** What is a watt? How many amperes does a 220-watt appliance draw on a 110-volt circuit? What is the resistance of this appliance in ohms? **8.** What is a kilowatt hour of electrical energy? **9.** What is the cost of operating five 100-watt lamps for 6 hours at 6¢ per k.w. hour? **10.** What is the cost of operating a 600-watt electric iron for five hours at 7¢ per k.w. hour? For seven hours at 5¢ per k.w. hour?

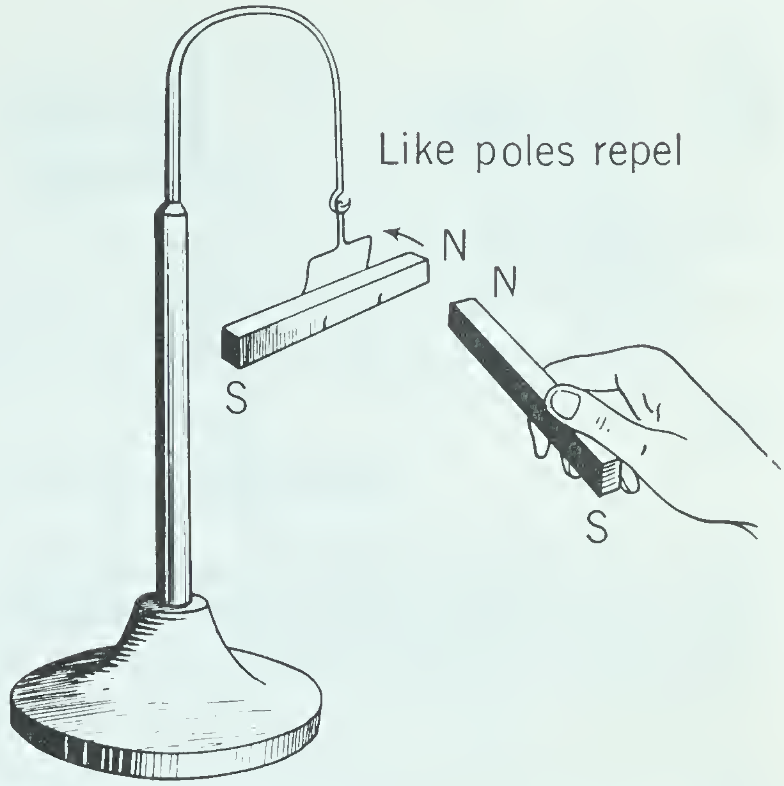


Fig. 11-21. Like magnetic poles repel each other. Unlike magnetic poles attract each other.

E What is magnetism?

Magnets are made of iron or alloys of iron, such as steel. Iron is attracted by a magnet. Therefore we say it has *magnetic properties.* Some forms of iron ore have magnetic properties. Such ores are found in Asia Minor and in the Adirondack Mountains of New York. We call these ores ***natural magnets.***

Steel will hold magnetism for a long time and is used to make permanent magnets. Soft iron and wrought iron make only temporary magnets because they lose the property of magnetism rapidly.

DEMONSTRATION

Suspend a bar magnet at the center so that it will turn freely. Keep the magnet away from iron (see Fig. 11-21). In what direction does the magnet point? Bring the north pole of another magnet toward the pole of the suspended magnet which points north. Results? Bring the other ends near each other. Result? Then bring the north pole near the south pole. Result?

Fill a small test tube about two-thirds full of iron filings. Do the filings attract a compass needle? Pass one end of a magnet along the test tube in the same direction several times. Do the iron filings now attract or repel the compass needle? Shake the test tube. Test for magnetism again. Result?

Touch the following substances with a magnet: copper, lead, iron, wood, and zinc. Which substance is attracted by the magnet? Put some iron filings on a glass plate. Put one end of a magnet under the glass. Will it attract the iron through glass? Repeat the demonstration, using first paper and then wood in place of the glass. Results? Put some iron filings in an iron pan. Does the magnet attract the iron filings through iron?

We call the ends of the magnets ***poles.*** One end is a north pole and the other a south pole. Unlike magnetic poles attract each other, but like magnetic poles repel each other. A magnet will attract iron, but not copper, lead, or zinc. It will act through most substances except iron. Glass is a nonconductor of electricity, but it does not prevent a magnet from attracting iron through it. Magnets are made in the shape of a straight bar, a U-bar, or a horseshoe. You can lift more with a horseshoe magnet because the poles are close together.

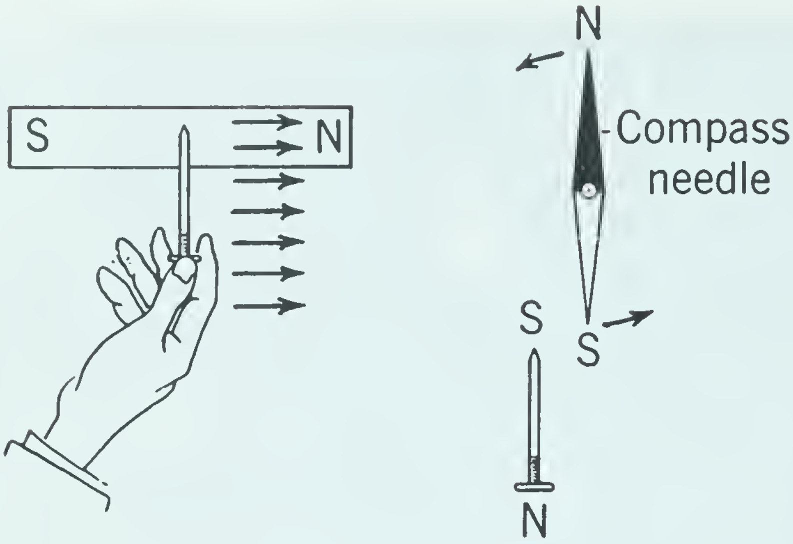


Fig. 11-22. The end of the nail which is rubbed toward the north pole of a magnet becomes the south pole. The other end is the north pole.

PUPIL ACTIVITY

Hold one end of an unmagnetized nail near the north pole of a compass needle, as shown in Fig. 11-22. Then hold the other end of the nail near the north pole of the compass. Result? Now with the N pole of a bar magnet rub one end of the nail, starting at the center and rubbing toward the end. Repeat several times and then bring the end of the nail near the compass. Result? Next, bring the other end of the nail toward the same pole of the compass. How is the effect of the magnetized nail different from that of the unmagnetized one? Is attraction a sure proof that an object is magnetized?

Each molecule of iron in the nail acts like a magnet. When the nail is unmagnetized, the molecules are irregularly arranged and as magnets they work against and neutralize each other. When the nail is magnetized, the molecules are rearranged so that all the like poles point in the same direction. That is why the nail shows magnetism and will attract iron or any other magnetic substance. The molecules of iron soon lose the arrangement caused by magnetization, and the nail loses its force of attraction. Molecules in magnetized steel tend to keep their arrangement, and thus the steel holds its magnetism for a longer time.

The affected space around a magnet is its magnetic field. If a magnet can influence or attract iron some distance away, then the force of the magnet must extend out quite far. This space is called its *magnetic field.* Two magnets floating on corks in a large jar of water will attract each other and pull themselves together. They tend to do the same thing when placed on a table. But friction against the table is too great for the attracting force between them, and they do not move toward each other.

There is an invisible force between the poles of magnets. The English physicist, Faraday, first used the term *lines of force* in 1831 to explain why magnets attract each other. We can think of these lines as acting like stretched rubber bands which tend to snap back into place.

Scientists think of lines of force as closed curves. They assume that the lines leave the north pole of a magnet, pass through the air, and re-enter the magnet again at the south pole. Then they travel through the magnet from the south to the north pole. Thus they make a complete circuit. Because more lines are concentrated at the two poles, you can see why the magnetic field is stronger in the regions near the poles.

PUPIL ACTIVITY

Put a bar magnet on the table. Put over it a heavy cardboard about one foot square.

Drop some iron filings on the piece of cardboard, from a height of one foot. Gently tap the cardboard. Result? Repeat the experiment, using a horseshoe magnet. Result? Put a piece of cardboard over the poles of two bar magnets with their unlike poles facing each other and two inches apart. What is the shape of the field between the two magnets? Repeat the experiment, putting like poles opposite each other. Result?

The iron filings become magnets and arrange themselves along the lines of force. They show the shape of the field around the magnet. You can also see that lines of force between like poles repel each other. If you move a compass needle from one end of the magnet to the other, the needle will point along a line of force as it moves along. This is why a compass needle points approximately north and south. The earth is a magnet with north and south magnetic poles, and has magnetic lines of force around it. The compass needle points along these lines of force as they pass from north to south pole.

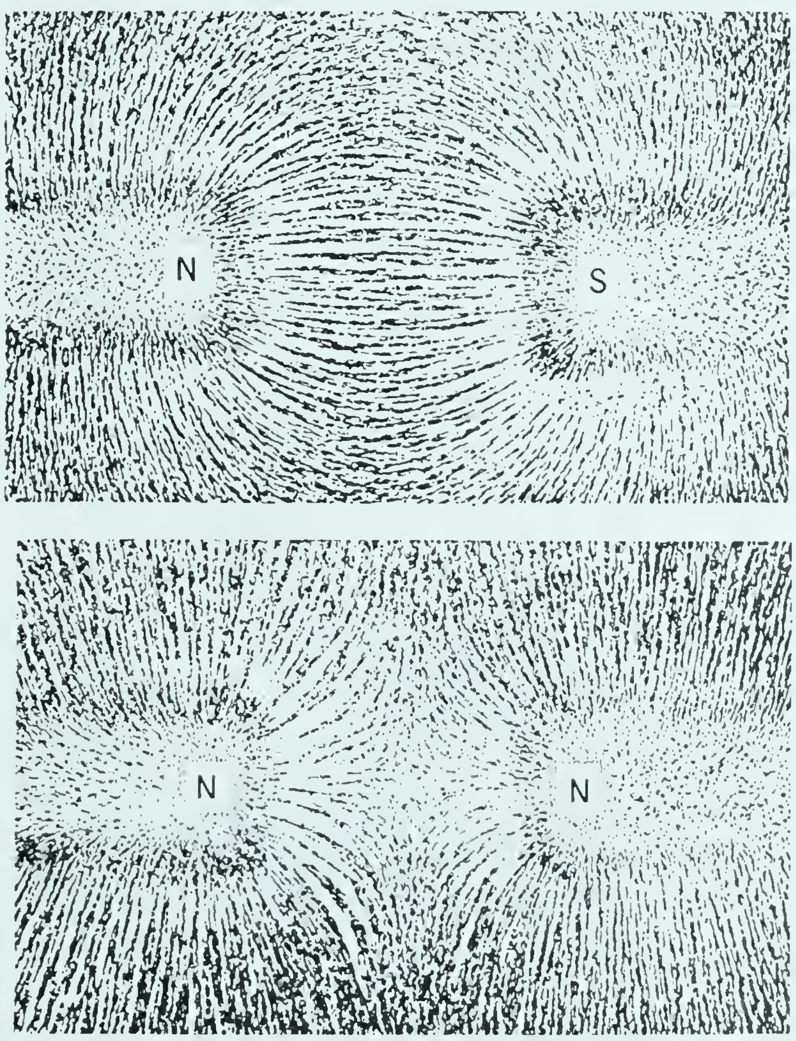


Fig. 11-23. Notice the difference in the lines of force between two unlike magnetic poles (top) and like magnetic poles (bottom).

REVIEW QUESTIONS

1. What is a natural magnet? **2.** What are the properties of magnets? **3.** What is the molecular theory of magnetism? **4.** How can you use a magnet to make a magnet out of an iron nail? **5.** Why does a compass needle point approximately north and south?

F What effects does an electric current produce?

An electric current flowing in a wire produces magnetic effects around the wire. Have you ever asked: "Just what has magnetism to do with electricity?" The Danish scientist, Oersted (*ur*-sted), answered this question. He found that a compass needle was deflected from its resting position if he brought near it a wire which conducted an electric current.

If an electric current makes a compass needle vary, the current produces some effect on it. What is this effect?

DEMONSTRATION

Connect a wire about three feet long to the poles of a dry cell. Hold a part of the

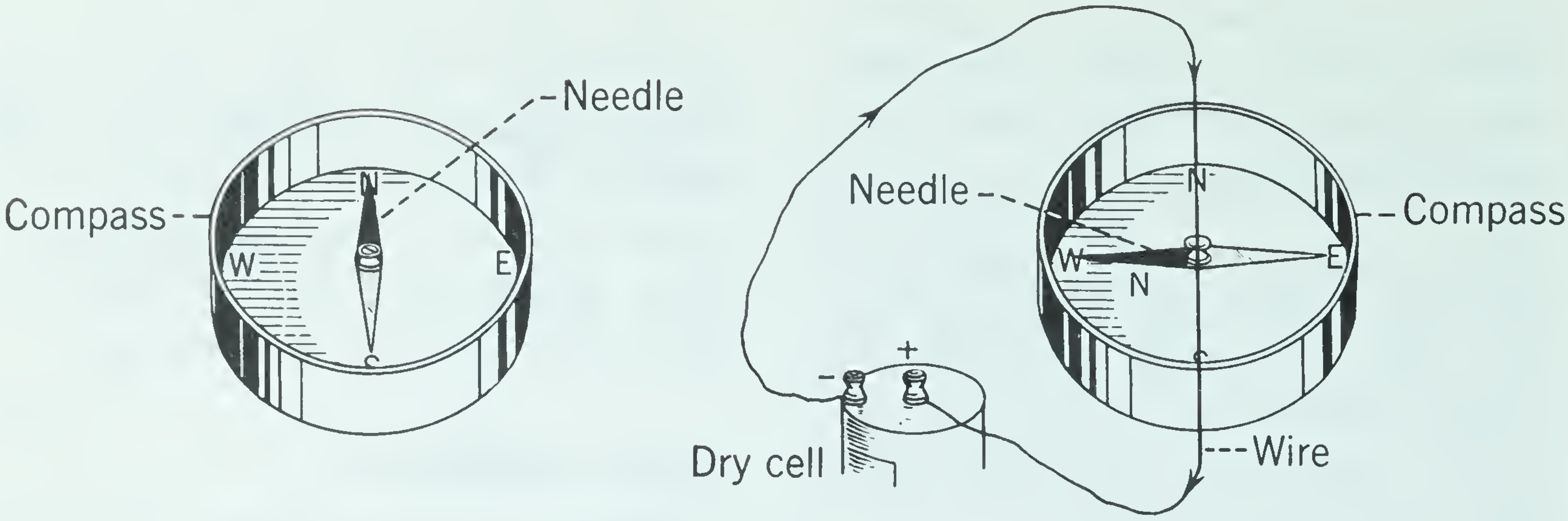


Fig. 11-24. The north pole of the compass needle will turn toward the west if the current flows through the wire from north to south above the needle.

wire horizontally in a north and south direction. Lower the wire over the compass needle (see Fig. 11-24). Result? Change the connections on the dry cell. This reverses the direction of the current. Again lower the wire over the compass needle. Result? Explain.

Next hold the wire in an east and west direction. Lower it over the compass needle. Result? Repeat all parts of the experiment by placing the wire under the compass needle. Move the wire slowly toward the compass needle in each case.

You can see that the compass needle is deflected when the wire is held in a north and south direction, but not when held in an east and west direction. The direction in which the needle deflects is reversed when the current is reversed. The needle deflects in an opposite direction when held under the wire.

What is the shape of the magnetic field around a wire that causes the needle to deflect in one position and not in the other?

DEMONSTRATION

Push a large copper wire through the center of a heavy cardboard about a foot square as shown in Fig. 11-25. Put the cardboard on some support that will hold it in a horizontal position. Sprinkle some iron filings on the cardboard. Connect the ends of the copper wire, which should be at least five feet long, with a battery of five or six dry cells in series. You can use a storage battery if one is available. Tap the cardboard gently, and then disconnect the battery. Result? What is the

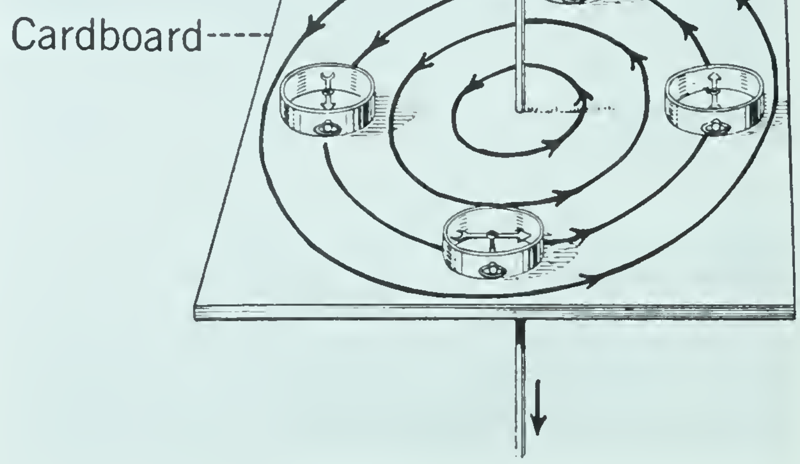


Fig. 11-25. The magnetic field around the wire carrying the current is in the shape of concentric circles.

shape of the magnetic field that surrounds the copper wire? Note in what direction the compass points as you move it in different directions around the wire.

The lines of force are in the shape of concentric circles at right angles to the wire. The stronger the current, the greater the number of lines of force and the farther they extend from the wire. There is a series of these lines of force, side by side, all along the wire. When you held the wire in a north and south direction over a compass needle, the needle pointed east and west. The needle did not vary when the wire was held east and west. This was because the lines of force were then in a north and south direction, or in the same direction as the compass needle.

The lines of force extend all along a wire. As long as the wire is straight, it is not possible to concentrate these lines of force. However, if you wind the wire in the form of loops, the lines of force inside the loops are closer together. This makes a much stronger magnetic field. All forms of apparatus that use electromagnets have the wire wound in loops.

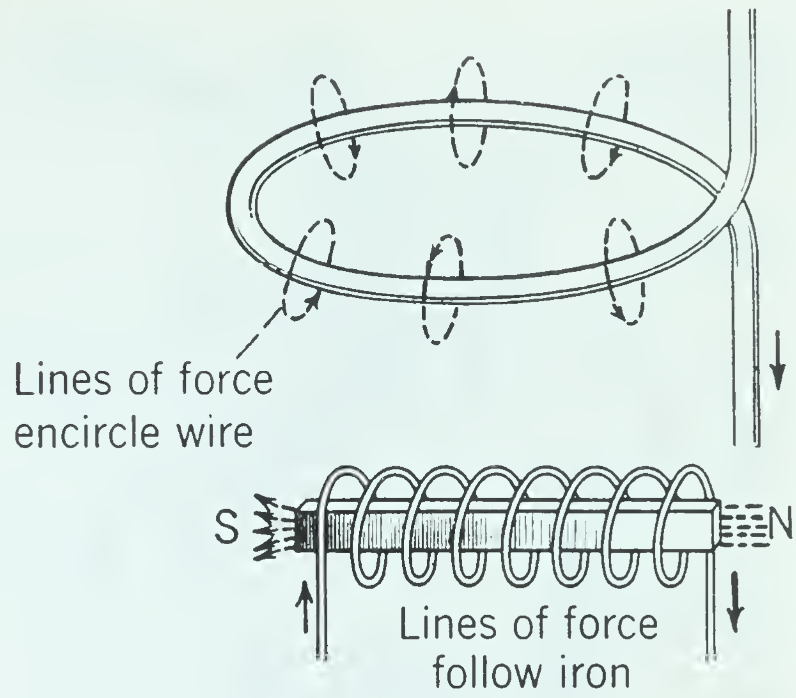


Fig. 11-26. In a coil of wire, most of the lines of force meet at the center of the coil. The iron core concentrates the lines of force, making a stronger magnetic field.

PUPIL ACTIVITY

Wind an insulated copper wire (3 feet long) in the form of a coil around a pencil. Connect the ends of the coil to a dry cell as shown in Fig. 11-27. Put a compass needle near one end of the coil. Result? Try the other end of the coil. Result? Put a nail in the coil. Is the strength of the electromagnet increased or decreased? Try picking up nails or a knife with the electromagnet. Result? Break the circuit. Result?

Reverse the connections of the electromagnet on the cell. Test with a compass needle. Have the poles of the electromagnet been reversed?

Wind three or four layers of small insulated copper wire around one arm of a U-shaped soft iron bar and continue the winding in an opposite direction about the other arm, as shown in Fig. 11-28. Connect the electromagnet with a dry cell. Is one end of the bar a north pole? Is the other end a south pole? How many nails can be picked up with the electromagnet? Break the circuit. Result?

Connect the electromagnet with two cells instead of one. Result? Unwind one-half of the coil on each side. Result? What two factors affect the strength of an electromagnet?

The coils should be made of insulated wire so that the various turns of wire do not touch each other. If uninsulated wires touch, the current will not pass through all the wires, but will be *short-circuited.* The stronger the

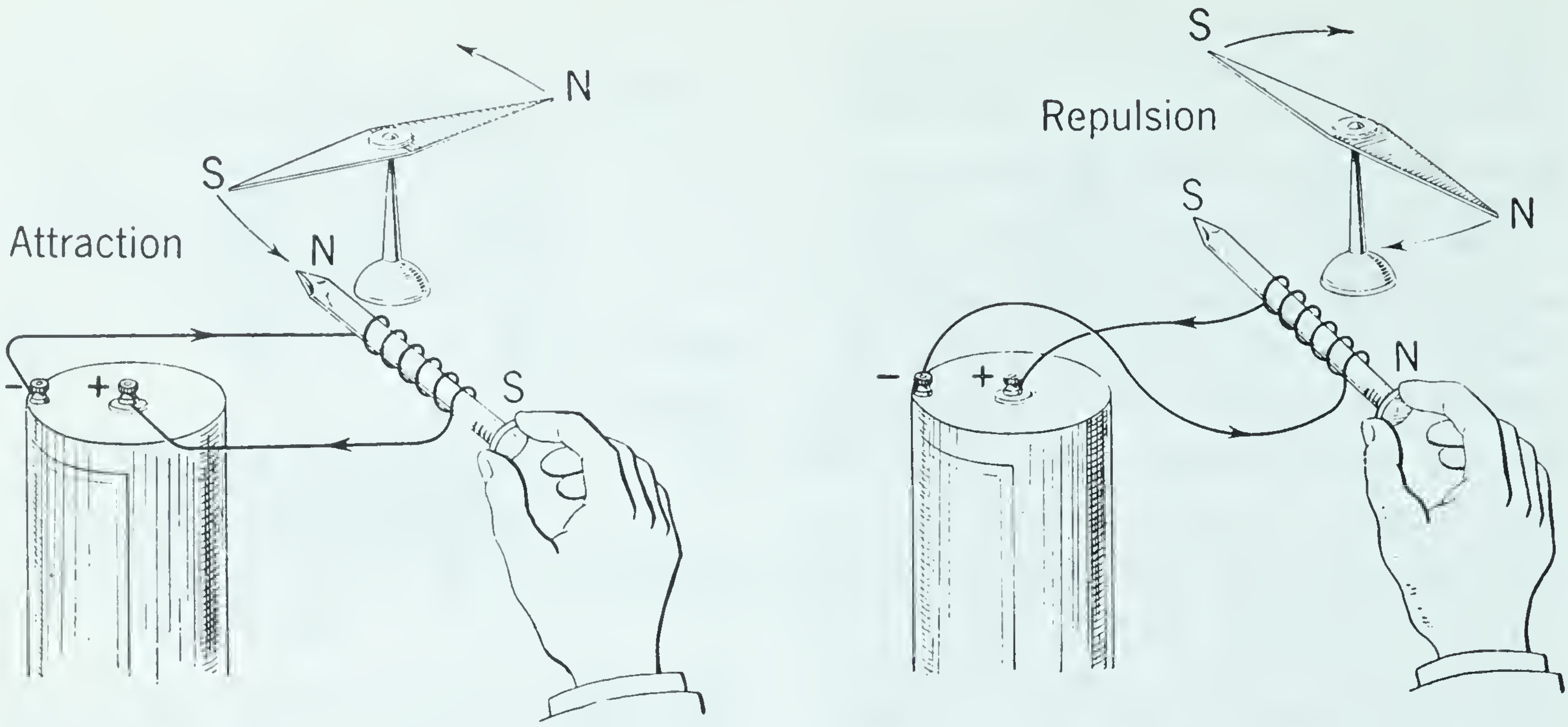


Fig. 11-27. An iron nail becomes an electromagnet when placed in a coil of wire which is conducting an electric current.

current and the greater the number of turns of wire, the stronger will be the electromagnet.

By now it is evident that an *electromagnet* is a device that consists of an *iron core* and *coils*. It is used in such familiar articles as electric bells, doorbells, fire alarms, and telephones. Without the electromagnet these devices would not operate.

We can change electric energy to heat energy. Crossed wires and short circuits often set houses on fire. You have noticed how the wires in a light bulb get white-hot. What happens in electric toasters, irons, heaters, when the current goes through them? They offer resistance to the electric current and change electrical energy to heat energy.

A long wire has more resistance than a short wire of the same size. A thin wire has more resistance than a thick wire of the same material. An iron wire has more resistance than a copper wire of the same length and size. The wire with the greatest resistance produces the most heat.

The tungsten wire in a light bulb is fine and long. This gives the wire

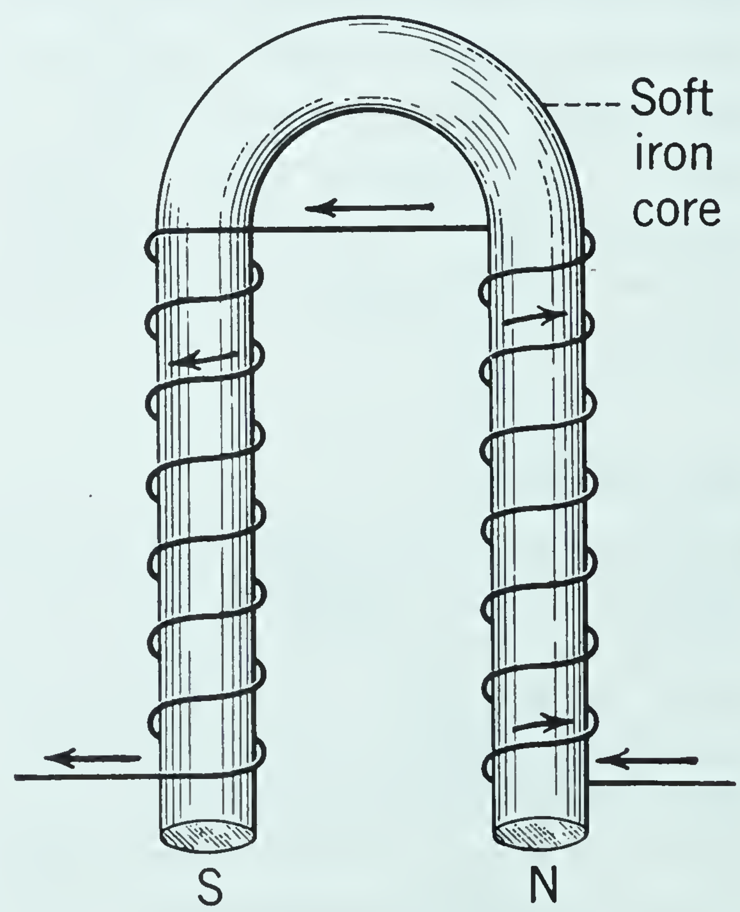


Fig. 11-28. A U-shaped iron bar becomes an electromagnet with north and south poles if the current is passed through wires wound around the poles in opposite directions.

enough resistance to make it white-hot when the current flows through it. All the air is removed from light bulbs. This prevents the wire from burning.

An electric iron has less resistance than a light bulb. Thus more current passes through it and produces more heat. In any electrical device, the quantity of heat produced depends on its resistance, the amount of current passing through it, and the length of time it is used.

Electric energy can be used to produce chemical changes. What will happen if you pass an electric current through water? Water is a poor conductor of electricity. But if you add a few drops of sulfuric acid to water, it will make the water a good conductor of electricity.

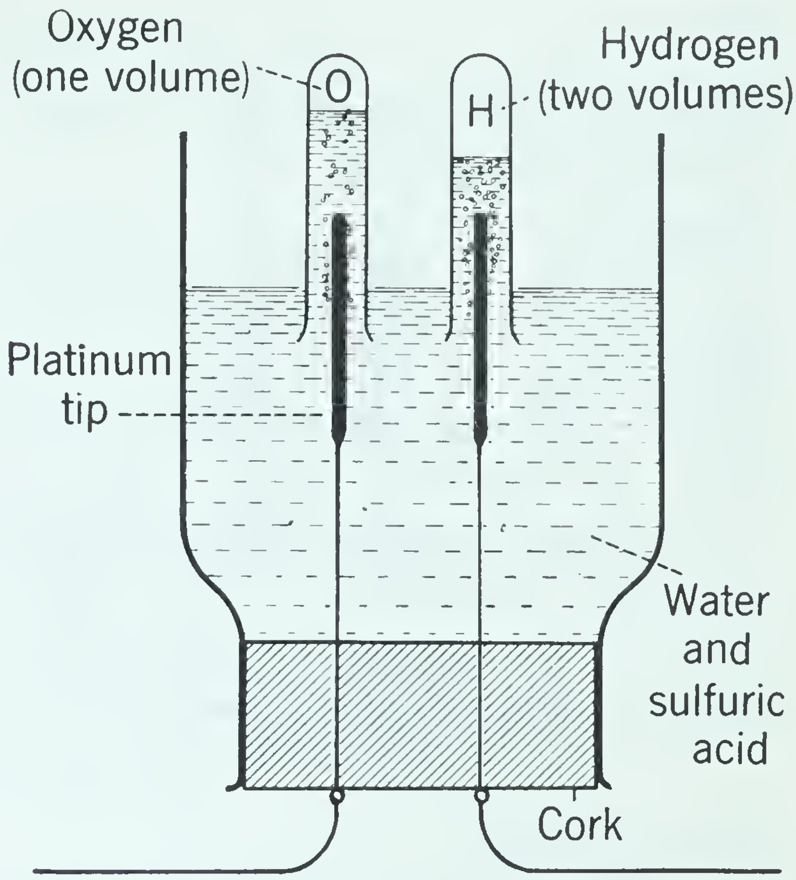


Fig. 11-29. An electric current will separate water into the gases hydrogen and oxygen.

DEMONSTRATION

Lower the ends of two insulated wires from a battery of several cells, or from a storage battery, in a vessel containing water and a small amount of sulfuric acid as in Fig. 11-29. The two wires must be tipped with platinum or with sticks of carbon. Pass the current through the solution. Result?

While the bubbles are rising, invert over each tip a test tube filled with water, and collect the bubbles. Does one tube fill faster than the other?

When each tube is filled, put your thumb over it and remove the tube for testing. With a flame test the tube that filled first. Result? What gas is present?

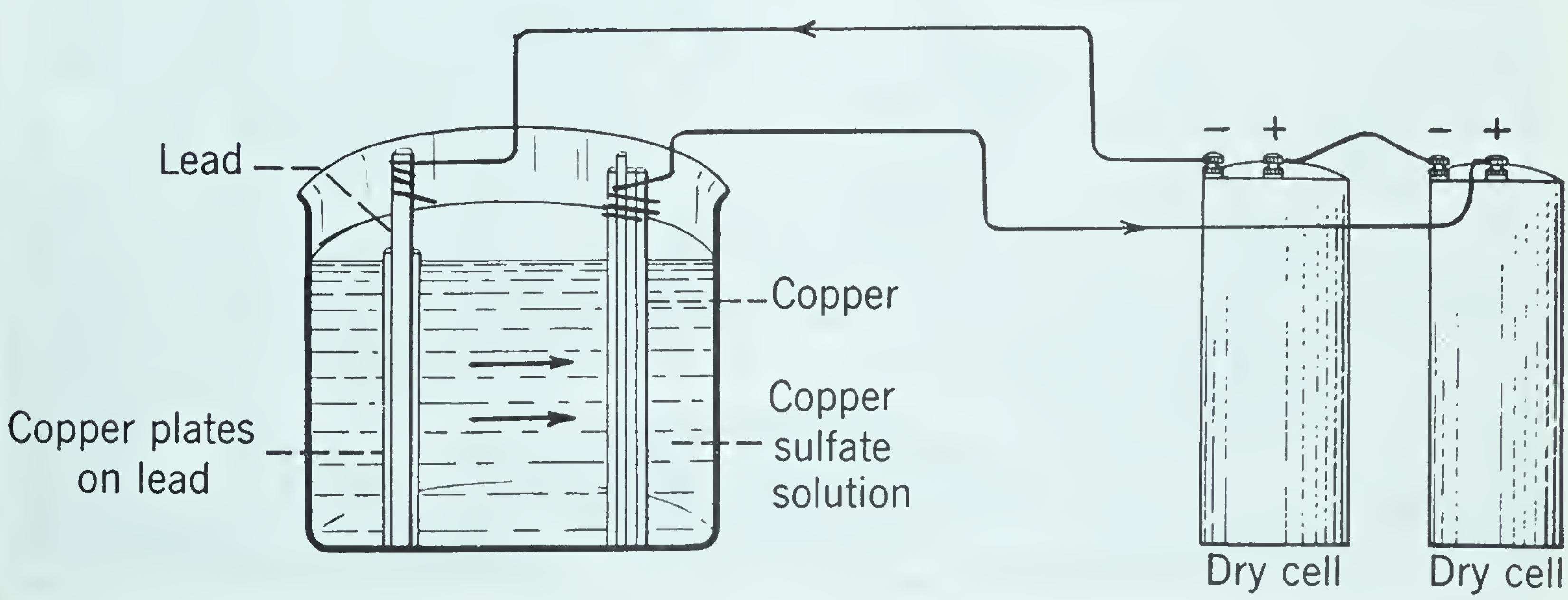


Fig. 11-30. The electric current is used to plate metals. This process is called electroplating.

Where did it come from? Now bring a glowing splint near the mouth of the other tube. Result? What gas is present and what is its source?

The electric current has broken down the water into two gases—hydrogen and oxygen. The volume of the hydrogen is twice that of oxygen. This shows that electric energy can be changed into chemical energy. It also shows the composition of water. Electricity is used to break up many compounds that are soluble in water.

PUPIL ACTIVITY

Mix crystals of copper sulfate and water in a glass beaker. Fit a clean piece of lead with a copper wire holder so that you can suspend the lead in the solution. Fasten a clean copper strip (4 inches long and ½ inch wide) to another wire. Attach the piece of lead to the zinc side of a dry cell (negative pole). Attach the copper strip to the center or positive pole. Put the lead and copper pieces in the solution (see Fig. 11-30). Now let the current flow through the solution for 15 minutes. Result?

Manufacturers use this same principle for plating objects with silver or gold. If the salt of a precious metal is dissolved in water, the flow of current through the solution deposits the pure metal on the object being plated. This process is called ***electroplating.***

The storage battery is still another example of chemical action caused by the electric current. Commercial storage batteries will deliver current immediately. For a demonstration, however, the cell must be charged before it will produce a current.

Fig. 11-31. Electroplating steel objects with silver produces the attractive tableware so common today.

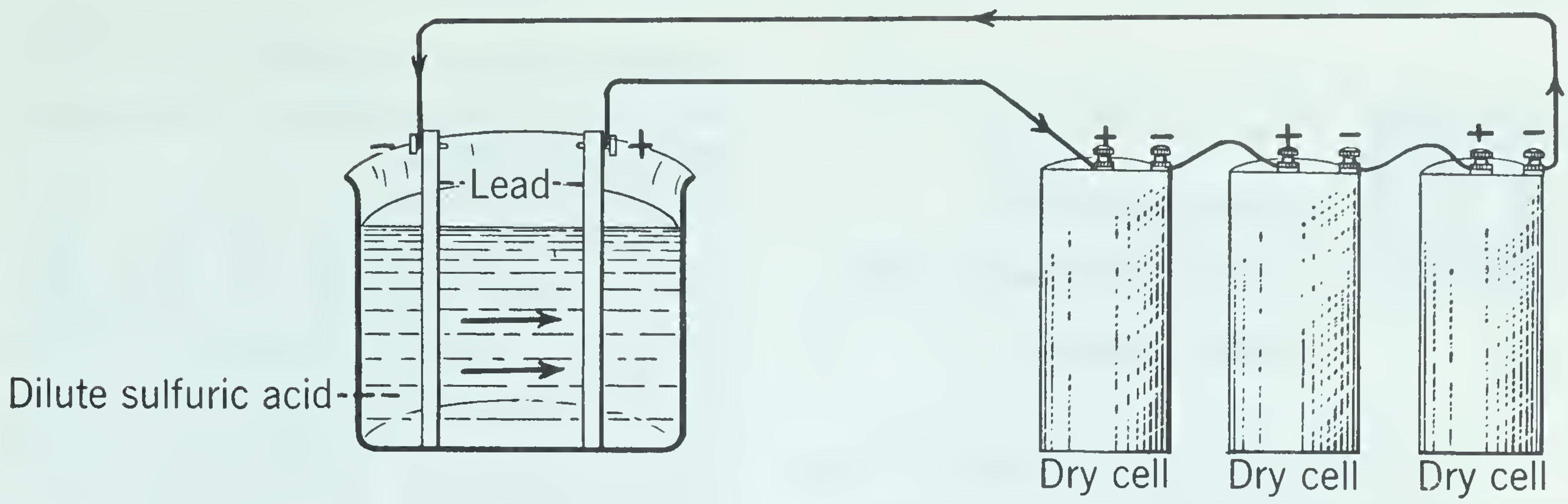


Fig. 11-32. A lead storage cell contains lead plates and dilute sulfuric acid.

DEMONSTRATION

Fill a beaker about two-thirds full of water. Add about one-tenth as much sulfuric acid. Add the acid to the water slowly and stir. (CAUTION: Do *not* pour water on the acid. The acid may spatter into your face.) Put two lead strips about four inches long and one inch wide in the solution, as in Fig. 11-32. Connect the lead plates with copper wires to an electric bell. Does the bell ring? Next, disconnect the bell. Connect three dry cells with the lead plates and pass the current through the solution for 15 minutes. Disconnect the cells. Connect the lead plates with an electric bell. Result?

Recharge the storage cell for about 30 minutes. Now connect the storage cell to a voltmeter. What voltage is produced? A lead plate storage cell should produce a voltage of two volts when it is fully charged.

Two other types of storage cells are the Edison cell and the nickel-cadmium cell. These are lighter in weight than lead cells. They are also stronger and less easily damaged by rough use. However, they are more expensive than lead cells, and deliver less voltage.

Chemical energy can be stored and changed to electrical energy to produce a current. A storage battery gives a large quantity of current (amperage). It furnishes current instantly to start your car. A good storage battery will return about 75% of the energy used in charging it. You can charge it several times and, with good care, it should last two years or more.

REVIEW QUESTIONS

1. What effect does a wire which conducts a current have on a compass needle? **2.** What is the shape of the field around a magnet? Around a wire conducting a current? **3.** Why can a stronger field be made by winding the wire in the form of a loop or coil? **4.** How is an electromagnet made? What determines its strength? **5.** What uses do we make of electromagnets? **6.** Which has more resistance, a thick or a thin wire of the same length and material? A long or short wire? **7.** Which has more resistance for the same size and length, an iron wire or a copper wire? **8.** Why is tungsten wire used in an incandescent lamp? **9.** What is the meaning of resistance as applied to electric circuits? **10.** How is an object electroplated? **11.** What materials are used to make a storage cell? **12.** How is a storage cell charged?

G How are electromagnets used to operate doorbells and electric motors?

The main parts of the electric bell are the armature, the electromagnet, and the circuit breaker. The iron core of the electromagnet attracts iron only when current flows through the coil. In the electric bell, the *armature* (*arm-uh-ture*) is of soft iron. It is alternately attracted by the electromagnet when the rest of the circuit is closed, and then released when the circuit is broken.

PUPIL ACTIVITY

Examine an electric bell. Where is the electromagnet? Where is the circuit broken in the bell? Use an electric bell having a key for closing the circuit. What makes the armature move? Trace the current of electricity from one binding post to the other. (NOTE: in some bells some of the wire is omitted, and the base of the bell serves as a conductor to one of the binding posts.) Note that the armature touches the contact screw. How does the current affect the iron cores in the electromagnet? What happens to the armature? Results?

Push the armature against the electromagnet. Is the spring now in contact with the screw point? Can the current pass through the coil? What happens to the electromagnet? Why is there a spring on the armature? Explain how the armature moves back and forth.

If the bell has a contact screw, turn the contact screw in. Result? Turn the contact screw out. Result? Can you stop the ringing by turning the screw out or in too far? Explain.

When you close the key, the armature is drawn toward the electromagnet. This makes the hammer strike the gong. The circuit is then broken in the bell and the electromagnet loses most of its magnetism. The spring on the armature then pushes it back against the screw and closes the circuit once again.

Bells are usually connected in parallel. If you have one, examine the bell system in your home. Find the key, battery, and wiring. Compare with the diagram in Fig. 11-34. In your home, perhaps you use a transformer which is connected to an outside wiring system. Find how it is connected.

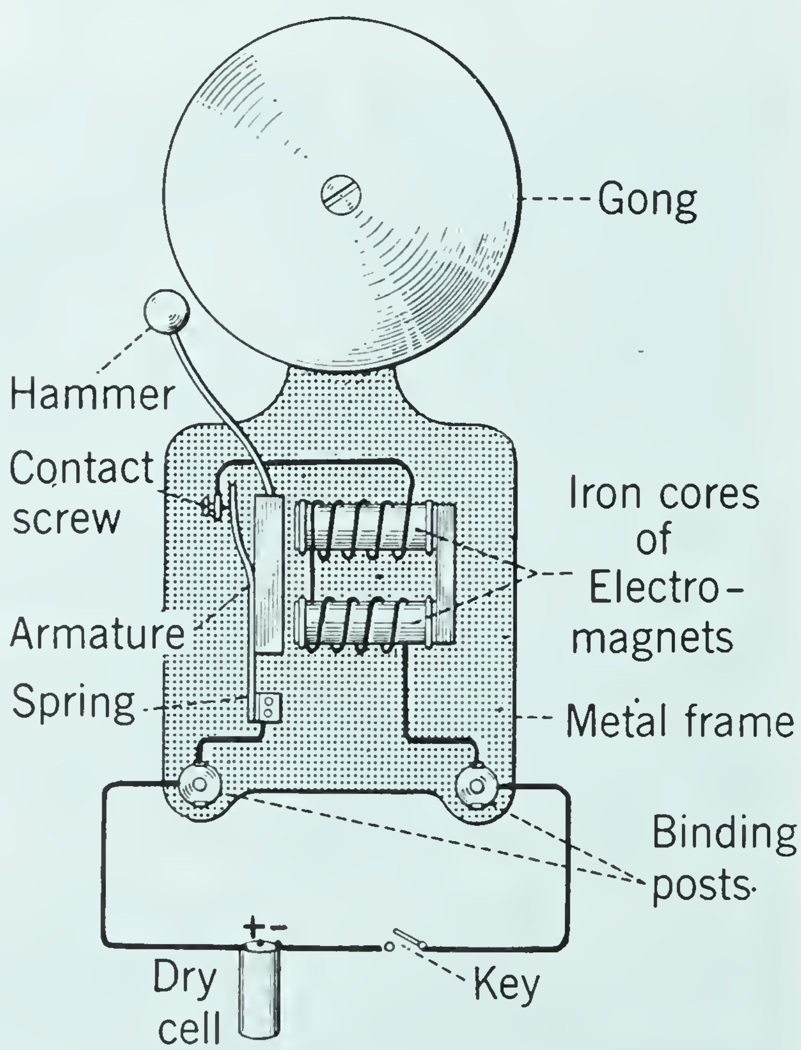


Fig. 11-33. In an electric doorbell, the armature is made to vibrate by the interruptions of the current through the electromagnets.

PUPIL ACTIVITY

Arrange a bell and two-key system on a board, as shown in the diagram in Fig. 11-35. Connect one dry cell in the circuit. Push the front-door key. Result? How could you use this system in your home, with one key at the back door? See if you can find out how the keys are connected in such an arrangement.

There are several kinds of keys that can be used. Some are switches, others push buttons. Their purpose is to make it possible to close and open a circuit. If you have a push button, take it apart and find how it is used to open and close a circuit.

Arrange a three-bell and three-key system as in the diagram in Fig. 11-36. Explain how each key is connected to ring all the bells independently of the other keys, using the same cell. If only one key is used, should the bells be in parallel or in series? Explain.

Bells are usually connected in parallel to lessen the resistance and to let one bell ring if the other is out of order. The keys are also connected in parallel. Then you can ring the bells from any one of the keys at the same time.

Many homes use door chimes instead of bells. If you have this system

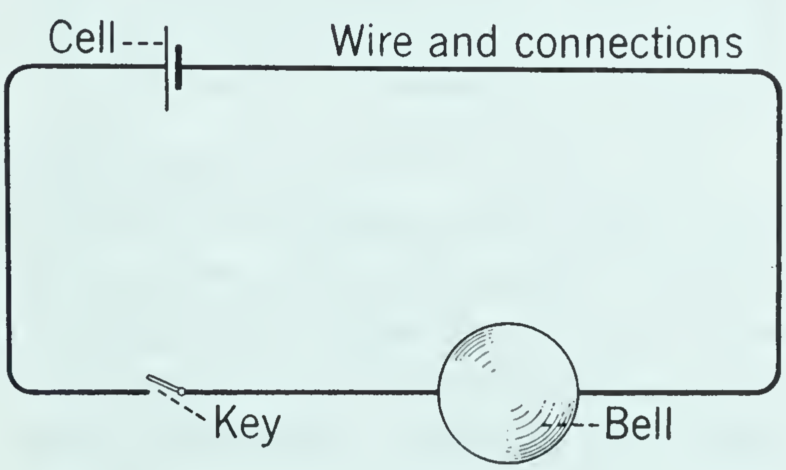


Fig. 11-34. The electric bell will ring only if the key is kept closed.

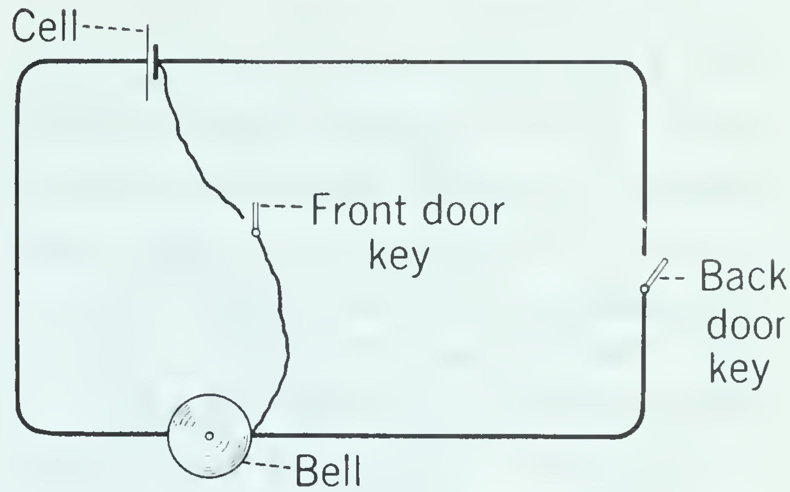


Fig. 11-35. Either key will ring the bell because they are connected in parallel.

at home, try to see how it works. Compare its operation with that of the bell which we have just studied.

The main parts of a D.C. motor are the armature, the magnetic field, the commutator, and the brushes. When the armature, which is wound with wire, is supplied with current, it becomes an electromagnet. One side or end of this iron core has a north pole and the other has a south pole.

The *commutator* (*kom*-mew-tay-ter) is a device for reversing the direc-

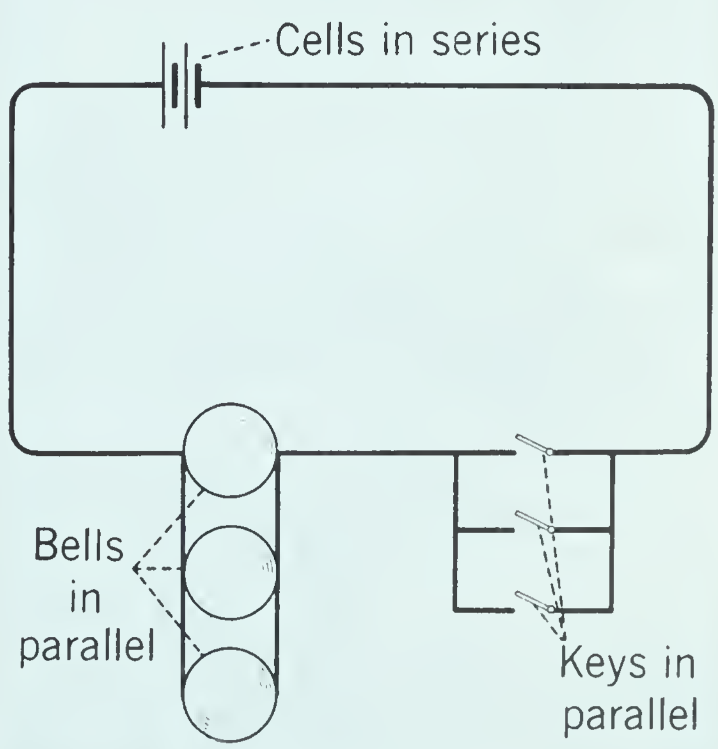


Fig. 11-36. Bells and keys are connected in parallel when all the bells are to be rung from either key.

tion of the electric current in the armature. The commutator is divided into two or more segments, which are insulated from each other. The ends of the poles of the iron core are made alternately north and south as it rotates. This is due to the current flowing through the commutator to the coils of the armature. The poles of the permanent magnets alternately attract and repel the poles of the iron core of the armature. With unlike poles there is *attraction.* With like poles there is *repulsion.* The armature rotates because of the alternate attraction and repulsion of unlike and like magnetic poles.

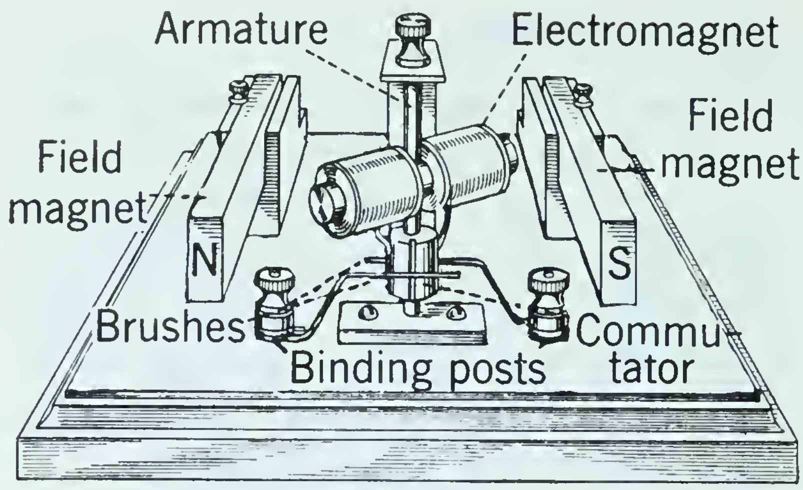


Fig. 11-37. In an electric motor, electric energy is converted into energy of motion.

DEMONSTRATION

Examine a toy motor as in Fig. 11-37. Use a St. Louis motor if possible, or construct a toy motor according to the directions given in many books. Find the bar magnets, called *field magnets,* which produce the magnetic field. Find the vertical shaft with the revolving electromagnet. This is called the *armature.* At one end of the armature shaft find a hard rubber ring in contact with two vertical strips on the outside. This is called the *commutator.* Do the metal strips touch one another? Can the current pass through hard rubber? Can electricity pass from one brush to the other through the brass strips? Explain.

Find where the ends of the wires from the electromagnet are attached. Note the two horizontal steel wires in contact with the rubber ring. These are the *brushes.* Each brush comes in contact with the small brass strips as the armature rotates. Note that the other end of each brush is connected to a *binding post.*

Be sure that the field magnets are in such a position that the north pole of one magnet is opposite the south pole of the other magnet. Connect two dry cells in series with the binding posts on the motor. What makes the motor go?

To answer the question better, note the movements of the armature. Trace the current of electricity from one binding post to the commutator. Now where does the current go? What happens to the electromagnet? When like poles of the electromagnet and the field magnets are near one another, what is the result? When unlike poles are near one another, what is the result? (Remember the law of magnets.) Show how the current is reversed in the electromagnet for each half-rotation. Just as the rotating armature is about to come to rest because unlike poles are near one another, what happens? Study the diagram in Fig. 11-37, showing how the current flows from one side of the commutator to the other side.

Now recall the laws of magnet action. When the north pole of the field magnet comes near the south pole of an armature magnet, the attraction causes the armature to rotate. As the poles are opposite one another, the commutator brushes change contact

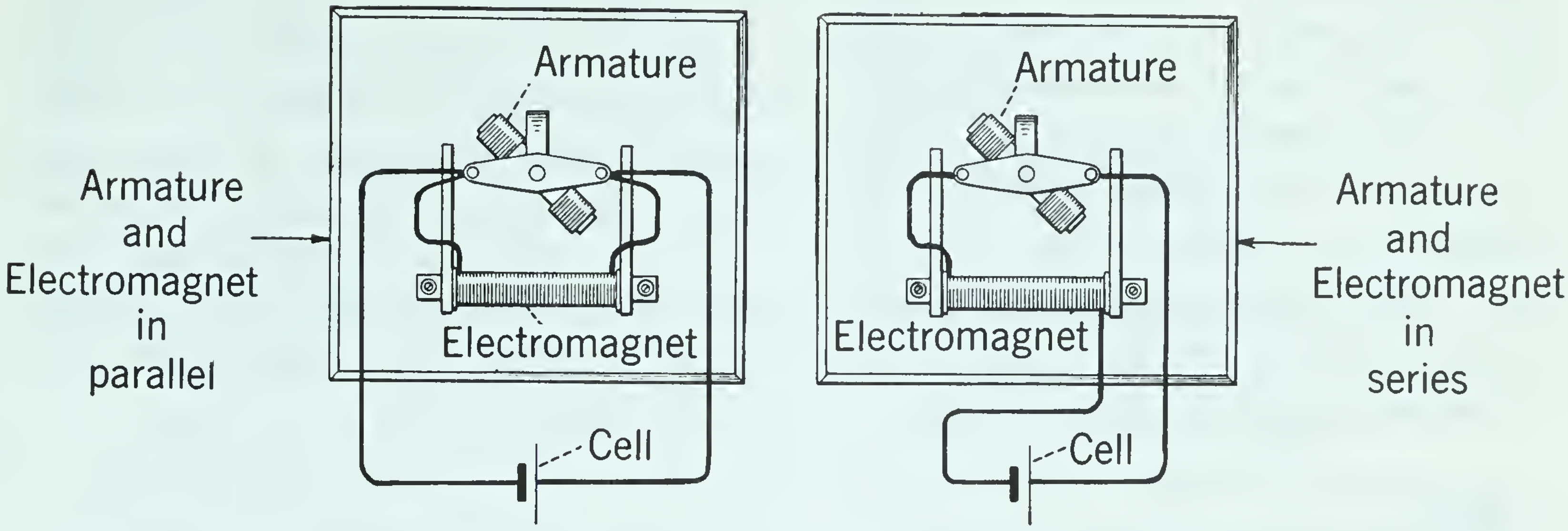


Fig. 11-38. The magnetic field in motors is usually supplied by electromagnets. You can connect them in series or parallel.

with strips in time to reverse the current through the rotating magnet. Thus they repel one another. Here is another exercise to help you understand how an electric motor operates.

PUPIL ACTIVITY

Wind a few turns of insulated copper wire about a large iron nail. Connect this electromagnet with a push button and a dry cell. Bring the head of the nail near the north pole of a suspended magnet. Press the button. Result? What polarity has the head of the nail? Now bring the other end of the nail near the magnet and press the button. Which pole is this end of the nail? If you carefully time the motion of the ends of your electromagnet, can you cause the suspended magnet to rotate?

You can substitute an electromagnet for the permanent magnets in the motor. Does the motor run better when the electromagnet is connected in series with the armature, or in parallel? How can you reverse the direction of the motor?

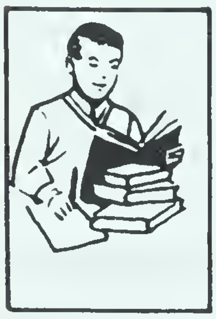
There are two types of A.C. motors. One type, the *series motor,* will also run on D.C. It is used in electric fans, vacuum cleaners, sewing machines,

Fig. 11-39. Electromagnets are often used to lift scrap iron and steel.

and many other household appliances. In construction it is much like the D.C. motor that you have just studied. The other type is called an *induction motor.* It will operate only on A.C. The two parts of an induction motor are the *stator,* or stationary part, and the *rotor,* which spins on its axis within the stator. There are no commutators or brushes in an induction motor.

REVIEW QUESTIONS

1. What are the parts of an electric bell? **2.** What makes the bell ring? **3.** What are the parts of a motor? **4.** What causes the armature to rotate? **5.** What is the purpose of the commutator? **6.** What is the chief advantage of an induction motor? **7.** If two keys are to ring the same bell, how should they be connected? **8.** Which type of electric motor can be used with either A.C. or D.C.?



QUESTIONS FOR REVIEW AND DISCUSSION

1. What was the earliest method used to produce electric energy?
2. What discoveries did the following men make in electricity: Volta, Oersted, Henry, and Faraday?
3. How is static electricity produced?
4. How is a voltaic cell constructed? Which metal acts as the fuel of the cell? What are the defects of such a cell?
5. How is a dry cell constructed? In what ways is this cell an improvement over the voltaic cell?
6. What is an electric current?
7. What are the properties of magnets?
8. What is the shape of the magnetic field around a bar magnet? A horseshoe magnet? Wire conducting a current?
9. How is an electromagnet made? What factors affect its strength?
10. How can the nature of magnetism be explained by the molecular theory?
11. Why are electric wires insulated? Do the magnetic lines of force pass through the insulation?
12. How are cells connected in series? In parallel? When should cells be connected in series? When in parallel?
13. How is water broken down into hydrogen and oxygen?
14. How are metals plated?
15. What materials are used to make a storage battery? How is the battery charged?
16. What advantages does a storage cell have over a dry cell? What disadvantages?
17. What units are used to measure the pressure, resistance, and quantity of current flowing in an electric circuit? What is the relationship between these units?
18. Under what conditions does an electric current produce heat?

19. Why is oxygen removed from an incandescent lamp?
20. What is a watt? A watt hour? A kilowatt hour?
21. How is the cost of electrical energy calculated?
22. What causes the armature of a motor to rotate?
23. How can the direction of rotation of a motor be reversed?

SPECIAL REPORTS AND PROBLEMS

1. Construct an electromagnet and explain its operation.
2. Construct three different kinds of cells and test their ability to produce currents over a period of time.
3. Construct a small electric heater.
4. Make a storage cell and charge it.
5. Electroplate some object.
6. Construct a simple electric motor.
7. Report on uses of electromagnets.
8. Report on the life and work of Michael Faraday.
9. What is the cost of electricity in your city compared with other localities?

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: static electricity, conductor, circuit, ampere, volt, ohm, watt, kilowatt, kilowatt hour, series circuit, parallel circuit, electroplating, electromagnet, magnetic field, commutator, armature, resistance, short circuit, conduit, alternating current, direct current, insulator, dry cell, wet cell?
2. How is electric energy produced in your community? How far is the power plant from your home? How is electrical energy sent from the power plant to your home?
3. How is the electrical energy as received from the power line distributed to all parts of your home?
4. What appliances used in the home are operated by an electric current?
5. How have theories helped to explain the nature of electricity?
6. What experiments have helped most in the development of the study of electricity?
7. Under what conditions is it more dangerous to handle an electric current? Less dangerous?
8. Under what conditions should series and parallel circuits be used?
9. In what ways is the field around a magnet similar to the field around a wire which is conducting an electric current? In what ways are they unlike?
10. Where are electromagnets used in the home?
11. What would you expect to happen under each of the following conditions?
    (a) An appliance constructed to operate on a 110-volt circuit was connected in a 220-volt circuit.

(b) A lamp constructed for a 120-volt circuit was used on a 100-volt circuit.
(c) A penny was put in a fuse box as the replacement for a fuse.
(d) An alternating current was used in the coils of an electromagnet.
(e) Two keys were connected in series to ring a bell from the front and back porches of a house.
(f) All the appliances in a house were connected in series instead of parallel.
(g) An alternating current was used in electroplating an object.
(h) One dry cell was used in a circuit with a six-volt flashlight bulb.

12. In what ways do we benefit from the following discoveries and inventions?
(a) Metals are plated with an electric current.
(b) Motors are made to rotate using an electric current.
(c) A wire carrying a current has a magnetic field around it.
(d) A wire is heated when an electric current passes through it.
(e) Edison invented the incandescent electric light.

13. What will it cost to operate a 600-watt electric iron for 20 hours at 5¢ per kilowatt hour?

14. What will it cost to operate six 100-watt lamps for 8 hours at 6¢ per kilowatt hour?

15. In copper plating an object,
(a) What metal must the solution contain?
(b) To what part of the plating cell is the object to be plated connected?
(c) What metal is used for the positive pole of the plating cell?
(d) What factors determine how much metal will be plated on the object?

16. According to Ohm's Law, the quantity of current flowing in a circuit is equal to the voltage divided by the resistance. In answering the following questions, assume all the necessary materials are available. You can verify your answers by experiment.
(a) How will the quantity of current flowing through a wire be affected by using two cells in series rather than one cell?
(b) How will the quantity of current flowing in the circuit be affected if two similar wires are connected in series instead of one wire, and the number of cells being used is the same?
(c) How must two bells and two keys be connected to two cells if both bells are to be rung loudly from either key?
(d) Two three-volt flashlight bulbs are to be connected to two cells, first in series and then in parallel. With which method of connection will the bulbs give the most light?
(e) Two cells are first connected in series with a flashlight bulb and then in parallel. With which method of connection will the bulb give the brighter light?
(f) If you were to connect a three-volt bulb to a six-volt battery and needed some resistance, would you connect the resistance in series or parallel with the bulb?
(g) How would you connect four dry cells if you were to use them to light a six-volt bulb?

The old

THE DISCOVERIES MADE BY SCIENTISTS IN THE NINETEENTH century laid a firm foundation for future generations. They could not realize that their discoveries would some day be the basis for one of our largest industries, the products of which affect greatly our daily lives.

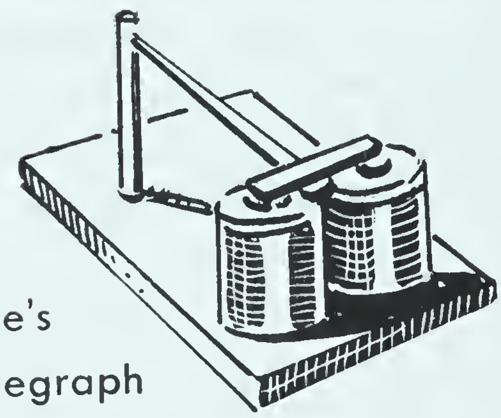
The invention of the incandescent lamp by Edison in 1879 was the beginning of rapid developments in electricity. Although the first dynamo was built in 1831, it had not been much improved by the time Edison invented his lamp. This discovery speeded up the improvement of the dynamo and the production of cheaper electrical energy.

The new

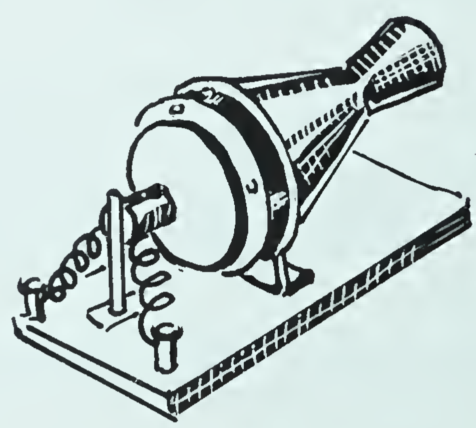
NEW METHODS OF CARRYING THIS ELECTRICAL ENERGY FOR long distances have made possible the building of large hydroelectric plants on rivers where there is a constant supply of water. In mountain regions, dams are built to store large quantities of water during the rainy season. This stored water is then used for power when there is little rain later in the season.

There are still many problems to be solved concerning radio, radar, telephone, television, and home appliances. But each year finds new improvements due to the active work of our scientists. In the future we may be able to furnish electric energy for our homes by use of the solar battery.

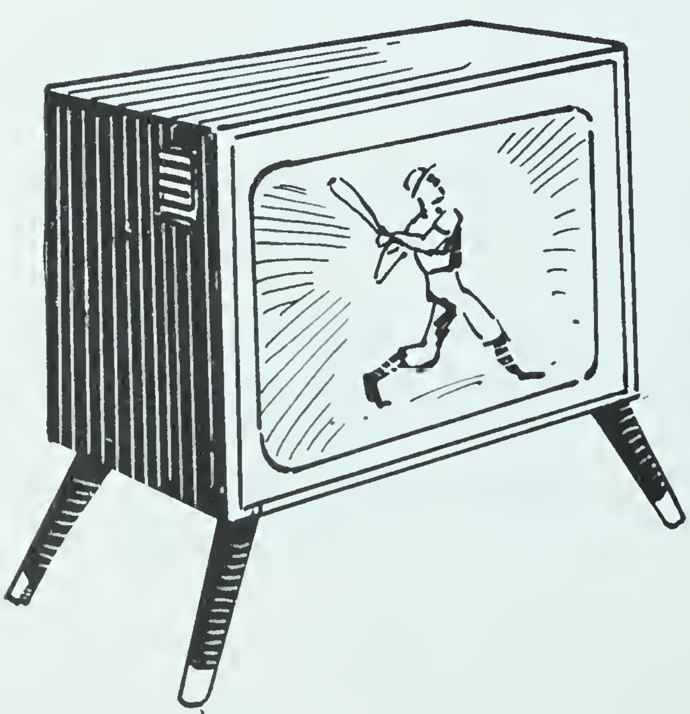
Primitive Communication



Morse's
Early Telegraph



Bell's Early Telephone



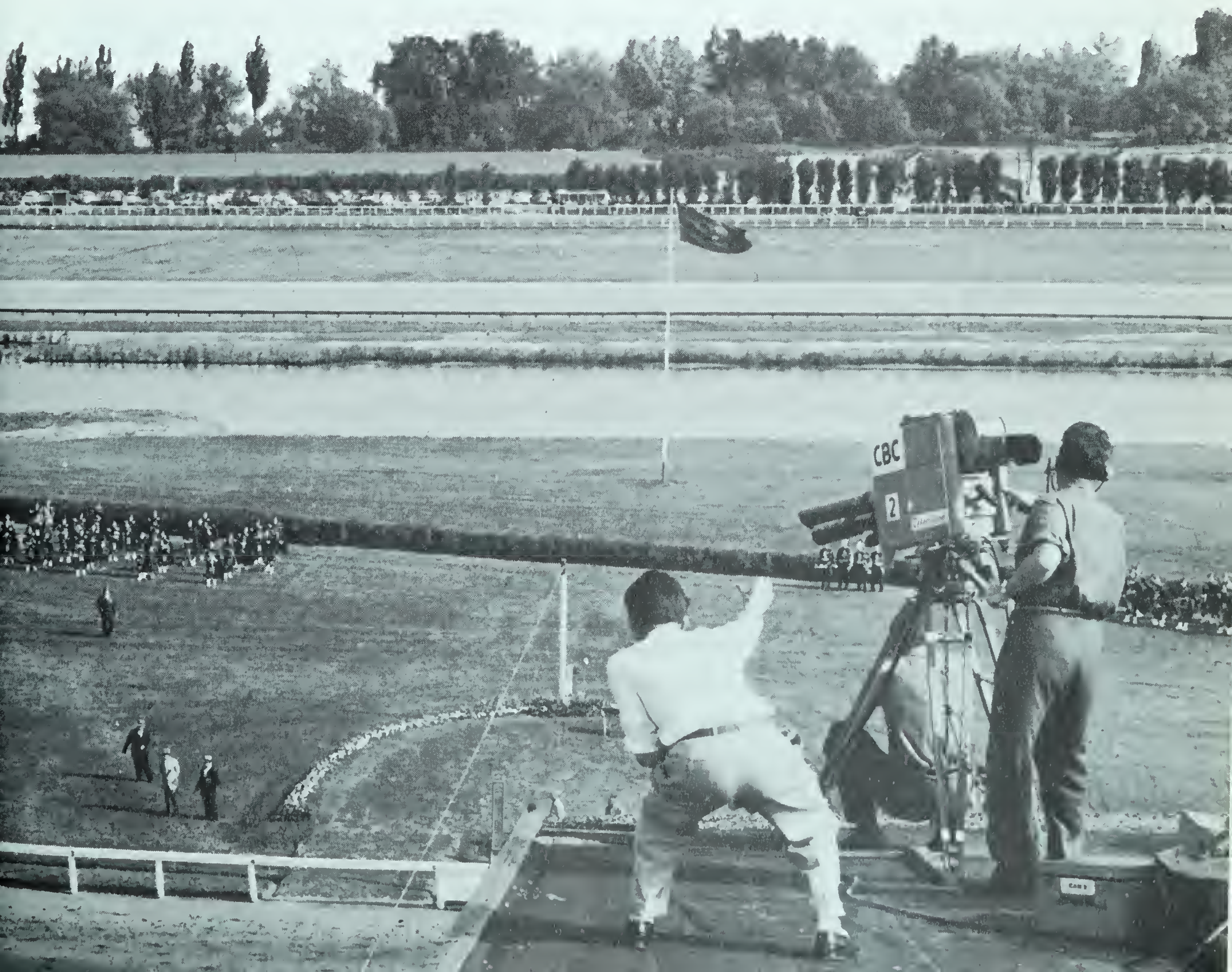
UNIT 12

DISCOVERY AND PROGRESS

How has man learned to send words and pictures long distances?

EARLY man sent signals by drum beats, flares of fire, and puffs of smoke. Later, runners ran from place to place carrying messages. This took quite a long time and often the messages got lost.

Then man began to build better roads and used horses or other animals to carry mail. Stations or posts were set up along the road at varying distances and relay riders carried mail from one station to the next. The rider was called a postman, so you can see where our present word comes from. Later, letters were carried by stagecoach and finally by railroad trains and airplanes.



The possibility of sending signals by electromagnets was first suggested in 1821. Ten years later, Joseph Henry used an electromagnet to produce signals which people could hear some distance away. But the first practical telegraph was made in America by Samuel F. B. Morse in 1837. His machine made dots and dashes on a moving slip of paper.

The original commercial telegraph line was built between Baltimore and Washington, D. C. The first message was sent from a room in the United States Supreme Court on May 24, 1844. Imagine the thrill for the eager men in Baltimore when the dot and dash signals came through and were translated to read: "What hath God wrought?"

For many years men tried to lay a telegraph cable across the Atlantic Ocean. One was actually begun in 1857, and after many setbacks, it was completed in August, 1866.

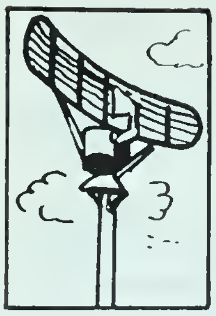
Alexander Graham Bell began work in 1875 on a musical telegraph. After about a year's work, he invented a crude apparatus which became the first telephone. Sending his assistant to another room, where one part of the apparatus was set up, Bell stayed in the room with the other part. He was very excited when he spoke into the mouthpiece: "Mr. Watson, please come here; I want you."

In a few weeks, Bell showed his new telephone in Philadelphia at the Centennial Exposition. He was disappointed when neither the judges nor the visitors were interested in it. When the young Emperor of Brazil came in, however, he came over to see the strange device. He stepped to one end of the line while Bell talked at the other. When he heard Bell's voice, he dropped the receiver and exclaimed, "Good gracious, it talks!"

In 1895 when Marconi (mar-*kone*-ee) was only 21 years old, he began experimenting with an idea. He thought that an electromagnetic vibration created by a series of electrical sparks, caused by an electric current being transmitted by air, could pass through any substance. He said that if it started in a certain direction it would keep going even without wires. Five years later, he took out patents in Italy for his first wireless. At first he could send messages only a few feet, then room to room, and later from one building to another.

People in Italy were not much interested in his discovery, so he went to England with it. Finally, in 1901 he arranged with assistants in Cornwall, England, to send a message to him across the Atlantic. He crossed the ocean and took up his station in a little shack at St. John's, Newfoundland. There he finally received the signal for the letter "S."

The next step in sending words instead of signals was soon developed, and the wireless telephone and the radio followed in rapid order. The radio wave is as swift as light. Through it man has won his greatest victory over time and space. With television, people in most parts of the United States can see and hear events as they occur.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How were messages sent over long distances in early times? **2.** How are dots and dashes produced in a telegraph set? **3.** What kinds of signals are sent in wireless telegraphy? **4.** How are messages carried over the telephone circuit? **5.** What are the difficulties in sending messages by radio? **6.** What is radar? How is it used? **7.** What makes television broadcasting so complicated?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

antenna	(an-*ten*-uh), a special type of conductor for sending and receiving electric waves.
audio frequency .	a term used in radio to indicate the rate of sound vibrations less than 20,000 per second.
electronics	the branch of the study of electricity that deals with the flow of electrons in vacuum tubes.
iconoscope	(eye-*kon*-oh-skope) the tube in the television camera that takes the picture.
photoelectric cell .	a device which produces a change in an electric current when the light which strikes the cell changes in intensity.
radar	(*ray*-dar), an electrical apparatus for locating the exact position of distant objects on land, in the air, and on water by means of radio waves.
radio frequency . .	a term used in radio to indicate the rate of vibrations higher than 20,000 per second.
relay	an electromagnetic instrument by which the opening or closing of one circuit opens or closes another circuit.
television	the process by which sound and pictures are sent from broadcasting stations.
wave frequency . .	the number of complete waves or vibrations per second.

A How are messages sent by sound, by light, and by electricity?

Sounds are carried by air, by solids, and by liquids. In Unit 10 we learned that sounds are the vibrations of some forms of matter. We found that the speed of sound in air is about 1,100 feet per second and that it takes about 5 seconds to travel one mile. To send a sound message through the air and receive a reply would take ten seconds if the two stations were one mile apart. However, we cannot hear even the loudest sounds very far away. The most powerful explosion can be heard only a few miles away.

Signals can be sent a few miles by light or by flags. The Navy sends signals from ship to ship by flashes of light. The time between the flashes can be changed to produce signals like the dots and dashes of the telegraph. These signals travel at the speed of light. But we use them only when lights can be seen by those receiving the messages. They would not be useful when the sun shines because you could not see them very far away.

Flags are used to send signals during daytime. The motion of the flags is visible because light makes it possible for us to see them. Regular messages can be sent this way, using different motions for certain code symbols.

Fig. 12-1. Flag signals are often used in daylight to assist airplanes in landing on aircraft carriers.

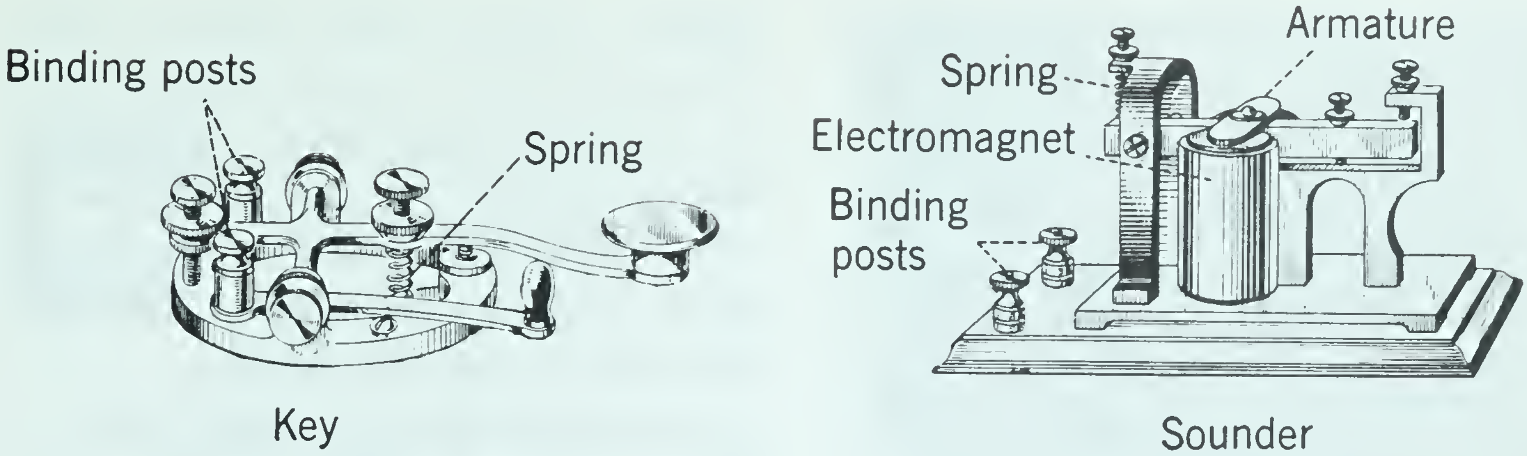


Fig. 12-2. The armature of the telegraph sounder is attracted to the electromagnet when the circuit is closed.

Messages can be sent by electricity. The telegraph is widely used to send messages over long distances. Such messages travel much faster than sound, but require an electric circuit for their transmission. A typical telegraph circuit includes at least one key, one sounder, and a cell or battery (see Fig. 12-2).

DEMONSTRATION

Connect a telegraph key and sounder with a cell as shown in Fig. 12-3. Push the key down and quickly release it. Result? Now hold the key down for a slightly longer period before releasing it. Result? How do telegraph operators make dots and dashes? What makes the armature of the sounder go up and down?

When the key is closed, the iron core of the electromagnet is magnetized and it attracts the iron bar on the armature. A click is heard when the armature strikes the sounding bar. When the key is opened, the circuit is broken. The iron core loses its magnetism and no longer attracts the armature. A spring then pushes the armature away from the electromagnet, striking the upper part and making a second click. The interval between clicks indicates a dot or a dash.

A code is needed to send telegraph signals. Samuel F. B. Morse, the inventor of the first practical telegraph, developed the code that bears his name. In this code, each letter and number is represented by two or more dots or dashes. With a code, long messages can be sent quickly.

The teletype consists of a telegraph sender with a typewriter keyboard, and a receiver that types the message in words. Teletype is used in sending the telegrams which are so familiar to you. Most of the news items you read daily in newspapers, or hear on radio

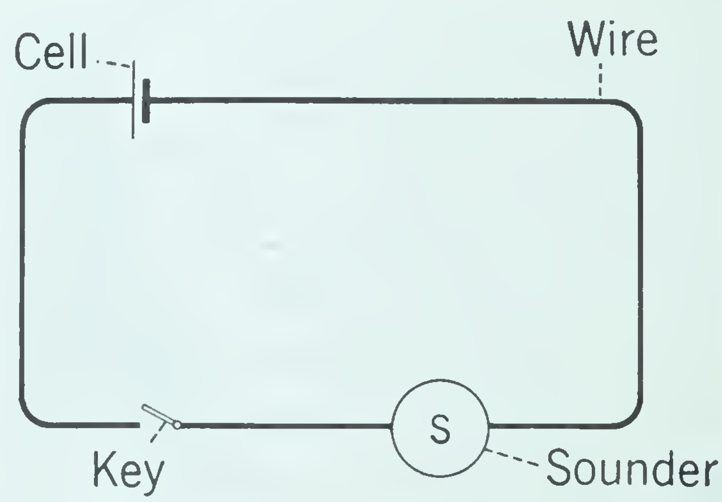


Fig. 12-3. When you open and close the key in the circuit, the telegraph sounder makes a series of dots and dashes.

Fig. 12-4. The teletype is an important device used today to send messages. It has replaced the former Morse Code method of sending messages.

or television, are sent by teletype. Stock market tickers work on the same principle as the teletype. In this way, stock market quotations can be received immediately in cities all over the country.

Telegrams are sent long distances by use of relays or vacuum tubes. A telegraph circuit such as you used in the Demonstration would be no use over a long distance. The electric current would become so weak that it would not operate a sounder. This difficulty can be overcome by using a *relay,* an instrument by which the opening or closing of a circuit carrying a small current opens or closes a circuit carrying a larger current. (See Fig. 12-5.)

This makes it possible to introduce another circuit at each station. It acts like an automatic key and is connected on the main line circuit. When any message is sent over the main line, the relay opens and closes the local telegraph circuit at the station. This automatically repeats the message.

In most modern telegraph systems a series of vacuum tubes, similar to the tubes in your radio, is used in place of the relay to strengthen the signals for long distance telegraph transmission.

REVIEW QUESTIONS

1. How long does it take for sound to travel a mile? **2.** Why is it difficult to send signals by light over long distances? **3.** How do telegraph operators make dot and dash signals? **4.** What are the parts of a telegraph circuit? Explain the use of each part. **5.** How is the teletype used? **6.** How are telegrams sent over long distances?

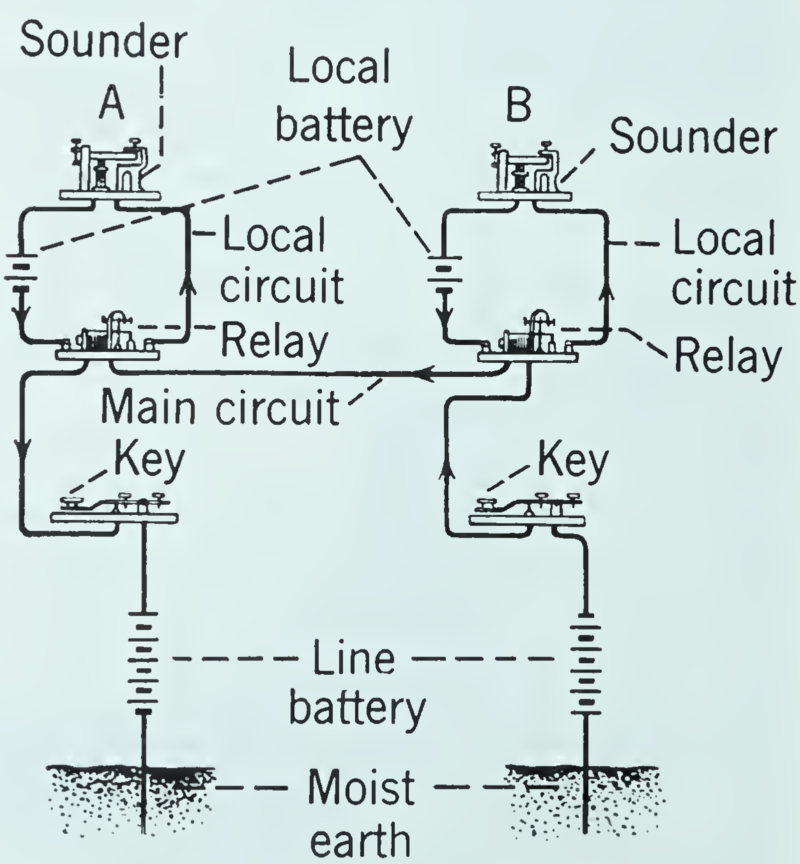


Fig. 12-5. A relay makes it possible to introduce another circuit at each station. The relays are connected in series on the main circuit.

B How are electric currents produced by induction?

An induced current can be produced by moving a magnet through a coil of wire. Batteries give *direct current,* which flows through wires only in one direction. It costs a lot to produce large amounts of current in this way. Then, too, it is difficult to send direct current over wires for long distances. *Alternating current,* which constantly and rapidly changes its direction through the wire, is usually more satisfactory.

DEMONSTRATION

Connect the ends of a coil consisting of many turns of fine insulated wire to a ***galvanometer*** (gal-vuh-*nom*-ih-ter). This is an instrument for measuring the strength of a weak electric current. Now quickly thrust a strong magnet through the coil as shown in Fig. 12-6. What is the effect on the galvanometer needle? Reverse the poles of the magnet and again thrust it through the coil. Does the needle of the galvanometer move in the same direction as before? Hold the magnet stationary in the coil. Result? Now, while holding the magnet stationary, move the coil back and forth. Result? Why do we call the current produced in this way an alternating current? How does it differ from a direct current?

If you move a coil of wire in such a way that it cuts magnetic lines of force, you get an induced current. If you cut the lines of force in a certain direction, you induce the current in one direction. If you cut the lines of force in the opposite direction, the direction of the current will also be opposite. There is no induced current when the magnetic lines of force are not being cut.

Generators produce alternating current, which is the kind that is delivered to homes in most cities. A ***generator*** is a machine for changing mechanical energy into electrical energy. In it, the electric current is produced by moving a magnet or an electromagnet through or past a coil of wire. There must be an engine of some sort to turn the armature in the generator or to move the strong magnets.

In a generator, coils of fine wire revolve in a magnetic field, or a magnetic

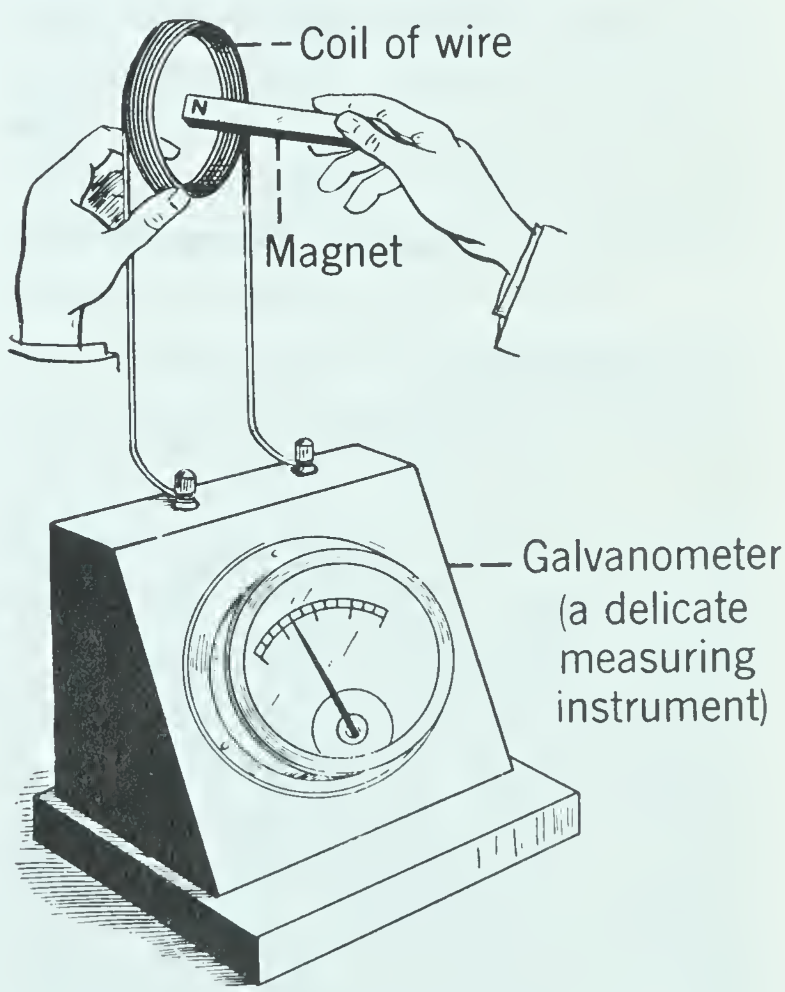


Fig. 12-6. The galvanometer is used to measure a weak electric current produced when a magnet is moved through a coil of wire.

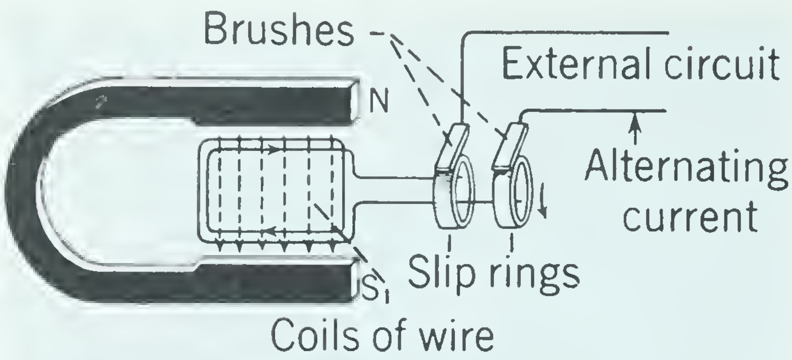


Fig. 12-7. The slip rings conduct alternating current from the armature.

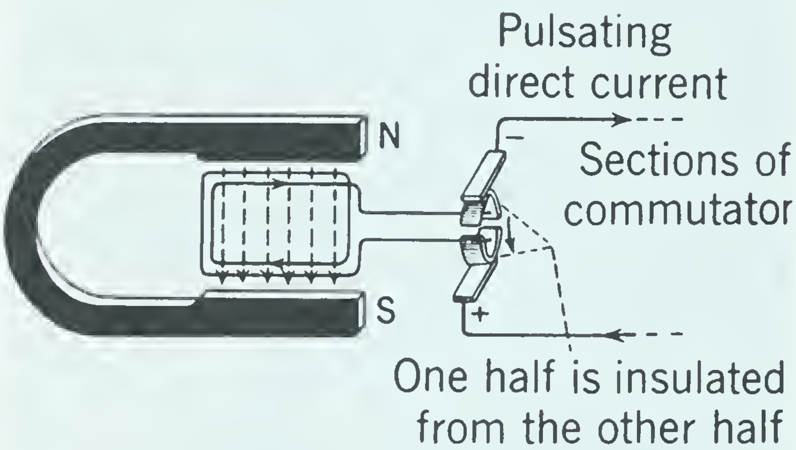


Fig. 12-8. The commutator changes alternating current to direct current.

field revolves around the coils. Thus it produces an alternating current. The current is led off through brushes made of metal or carbon. You can change the alternating current produced in the armature to direct current by using a commutator, as you learned in Unit 11.

DEMONSTRATION

Examine a toy generator or motor (see Figs. 12-7 and 12-8). Find the revolving coils of wire called the *armature*. Find the electromagnet. Sometimes a permanent magnet is used. Find strips of copper or wire brushes that are in contact with the rotating axis of the armature. See if this axis is split into segments that correspond to the armature coils. If so, this is called a commutator. It changes the induced alternating current into direct current. Connect wires from the binding posts of the motor or generator to a galvanometer. Spin the armature with your finger. How does the galvanometer needle move? Is this an A.C. or D.C. generator? How could you change it to make it produce the opposite type of current?

The voltage produced by a generator depends on the number of magnetic lines cut each second. The amount of current varies with different generators. To get a large voltage you need a strong magnetic field, many turns of coiled wire, and a generator which revolves rapidly. Each turn of wire cuts magnetic lines so it is easy to increase or decrease the voltage by changing the coils of the generator.

An alternating current flowing through one coil of wire can induce a current in another coil. When you have a magnet in a coil of wire, you get no voltage unless you move either the coil or magnet. A coil of wire has a magnetic field around it when a current is flowing. This magnetic field, if moved through a second coil, should induce a voltage in that coil. However, a more rapid change can be produced in the field of the primary coil by opening and closing the circuit.

DEMONSTRATION

Get or make a coil of about 50 turns of No. 24 insulated copper wire. Make a second coil of three or four hundred turns of smaller insulated copper wire, large enough for the smaller coil to pass through it. The coil with the smaller number of turns is the *primary*, and the one with the larger number of turns the *secondary*. Connect the secondary coil to a sensitive galvanometer (see Fig. 12-9). Connect the primary to two or more dry cells connected in series. Put an iron

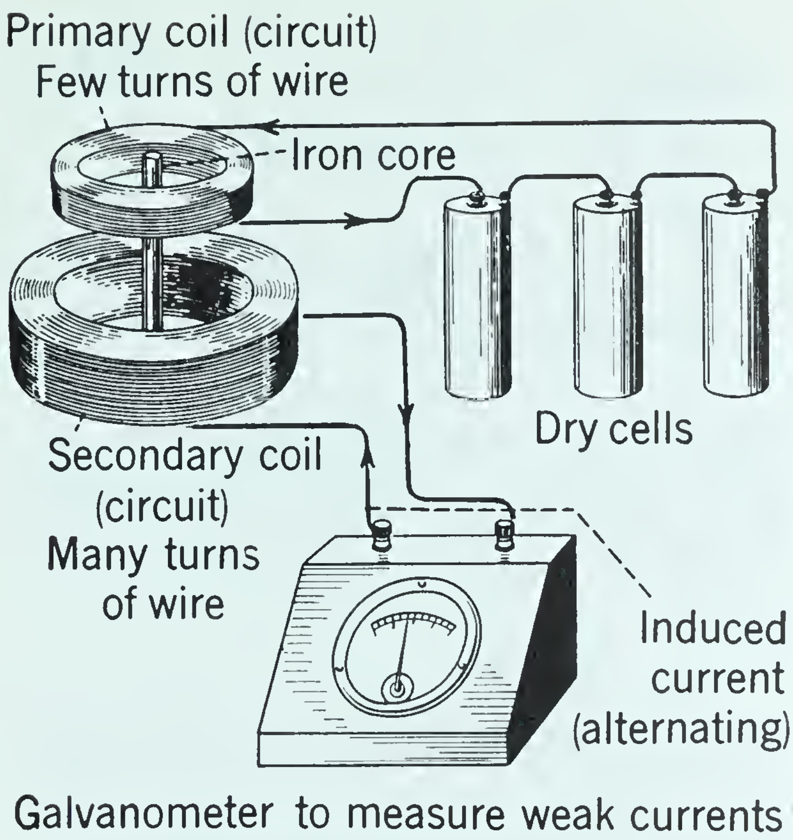


Fig. 12-9. By changing the strength of current in the primary coil, an induced current can be produced in the secondary coil.

core through the primary. Put the primary inside the secondary. Move the iron core back and forth. Result? Draw the primary back and forth. Result? Move the secondary back and forth. Result? Disconnect one wire from the cells. Result? Touch the pole with the wire again. Result? Make and break the circuit rapidly by touching the wire to the pole. Result? Add another dry cell to the circuit and repeat the experiment. Result?

You can see that a current is produced in the secondary coil whenever the strength of the field around the primary coil is increased or decreased. A changing number of lines of force in the primary coil causes an induced current in the secondary coil. You can change the strength of the field by moving the coil or by making and breaking the circuit. If an alternating current is sent through the primary coil, you do not have to move the coils or break the circuit to produce an induced current. The strength of an alternating current is changing constantly. It gets weaker, then stronger, then weaker again, as it changes direction. The use of a higher voltage in the primary induces a stronger current in the secondary circuit.

In a step-up transformer an alternating current is sent through the primary coil. If there are 20 times as many turns in the secondary coil as in the primary, the voltage will be multiplied 20 times. Also, the secondary amperage will be decreased to one-twentieth. On power lines the voltage on the line is increased and the amperage is decreased. This makes it possible to send electricity long distances with less loss due to heat, and to use smaller wires. Smaller wires, in turn, require fewer transmission towers. Also, the towers do not need to be as strong as they would if heavier wires were used.

In the *step-down transformer* near your home, the current is sent into the secondary circuit and removed from the primary circuit. The voltage is decreased and the amperage is increased.

REVIEW QUESTIONS

1. What is an induced current? **2.** How can a magnet and a coil of wire be used to produce an induced current? What kind of current is produced? What factors determine the strength of the current produced? **3.** What are the principal parts of a generator? **4.** What is the purpose of the commutator on some generators? **5.** How can a current be induced from one coil to another? **6.** What are transformers and how are they used?

C How are telephone messages sent over wires?

The telephone transforms sound vibrations into a varying electric current. When you speak into the mouthpiece, or *transmitter,* the sound vibrations cause the *diaphragm* (*dy*-ah-fram) to vibrate. See Fig. 12-10. When a sound wave compression hits the diaphragm, it presses the carbon granules in the transmitter closer together. This lowers their resistance so that more current can flow. A rarefaction reduces the pressure on the granules, causing their electrical resistance to increase. Thus less current flows. In this way sound vibrations are converted into a varying electrical current, which flows through the *primary* of an induction coil.

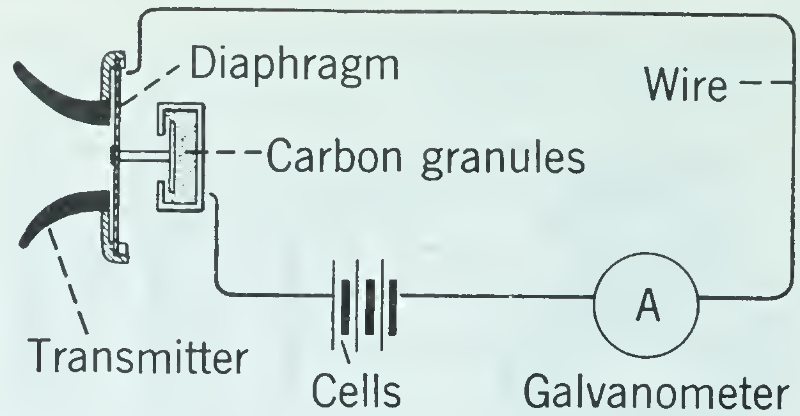


Fig. 12-10. The vibrating plate of a telephone transmitter causes the carbon granules to vary the resistance of the circuit, thus causing the strength of the current to vary.

The changing current in the primary circuit induces a current in the *secondary* circuit. In talking, the frequency is 100 to 200 vibrations per second. The diaphragm vibrates in unison with the voice vibrations, and the electrical vibrations pass over the wire at the same frequency.

DEMONSTRATION

Connect 3 dry cells, a galvanometer, and a telephone transmitter in series, as in Fig. 12-10. Remove the mouthpiece.

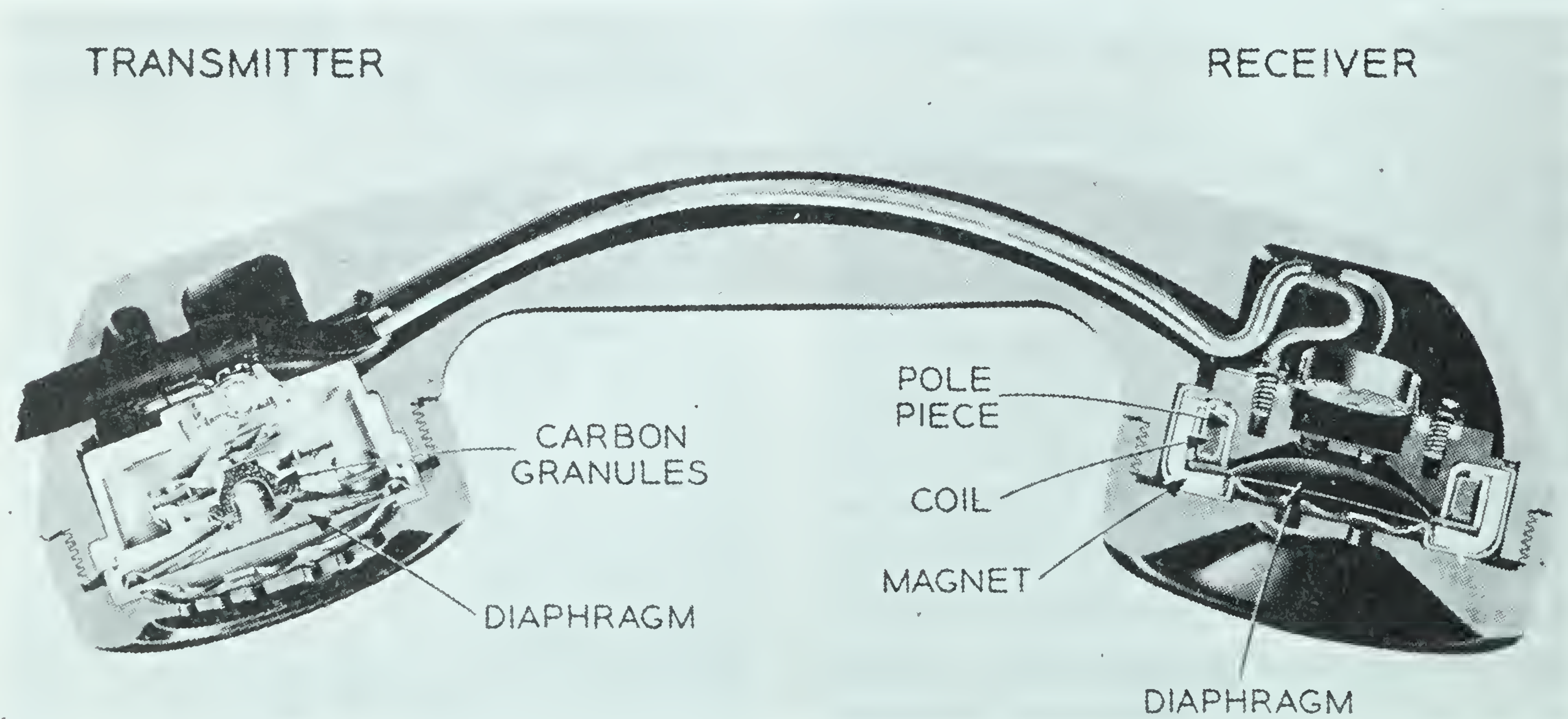


Fig. 12-11. This cutaway diagram shows the various parts of a modern telephone handset.

Read the galvanometer. Now press the diaphragm of the transmitter in, and again read the galvanometer. Release the diaphragm. What is the result?

How could a telephone diaphragm cause carbon particles to be pressed closer together? How would this affect a current sent from the transmitter to a distant receiver? On what would the number of vibrations or pulsations and their intensity depend?

Connect in series a telephone transmitter, four or more dry cells, and a coil of wire with at least 50 turns. The coil used to produce an induced current previously will be satisfactory. Put the coil with 50 turns inside another coil with at least 400 turns. Put an iron core in the primary coil. Connect a galvanometer to the secondary coil. Replace the mouthpiece in the transmitter. Blow quickly into the mouthpiece. Result on galvanometer? What is produced in the secondary coil? Inhale and exhale rapidly in the mouthpiece. Result?

Next, disconnect the galvanometer from the secondary circuit. Connect a telephone receiver to the secondary coil.

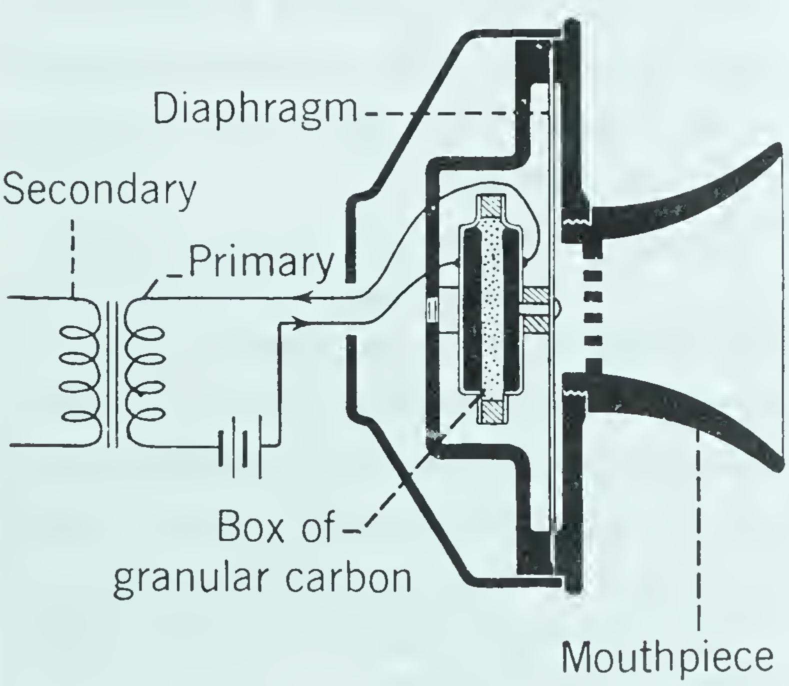


Fig. 12-12. The diagram above shows a cross section of a telephone transmitter and its circuit when they are connected to a transformer or induction coil.

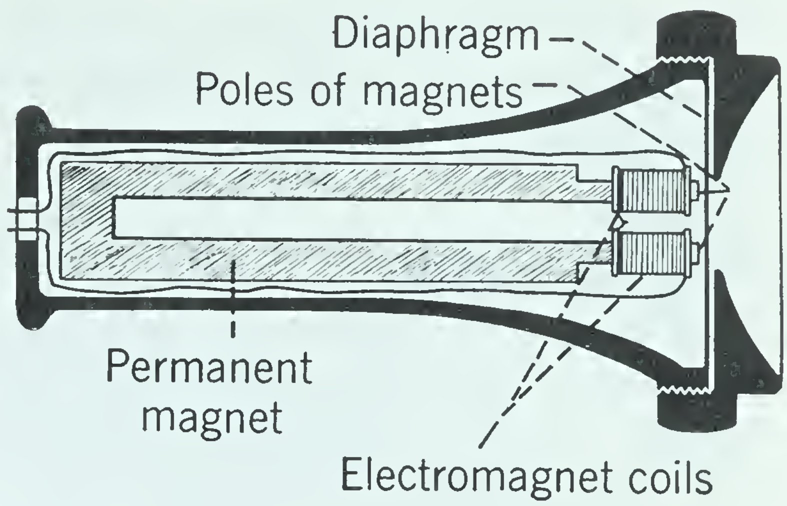


Fig. 12-13. Here you can see the interior of a telephone receiver with its magnet and coils.

Hold the receiver near your ear. Blow quickly against the mouthpiece. Result? The apparatus is now ready for one-way telephoning. If a long wire is used to connect the receiver with the secondary coil, it will be possible to speak into the transmitter and to hear the words in the receiver.

The telephone receiver consists of a diaphragm, a permanent magnet, and two electromagnets. If you remove the cap of the receiver, you can see the parts easily. The poles of the permanent magnet are wound with fine insulated wires to make two electromagnets. The diaphragm is placed close to the poles of the permanent magnets. The current flowing through the coils is pulsating. This produces changes in the strength of the magnet. When more current flows, it is stronger and when less current flows, it is weaker.

The diaphragm vibrates according to the changes in the strength of the magnet, thus producing the sounds you hear. Your voice over the telephone sounds differently from your natural

voice because the telephone is not able to reproduce all of the overtones of your vibrating vocal cords.

REVIEW QUESTIONS

1. What are the parts of a telephone transmitter? **2.** What causes the diaphragm in the transmitter to vibrate? **3.** How are sound waves changed to electric waves? **4.** How does the receiver work? **5.** Why is your voice over the telephone different from your natural voice?

D How are messages sent through space by radio?

Radio waves travel long distances through space; sound waves travel only short distances. A radio message may travel around the world, but the actual sound does not go much beyond the microphone. This is somewhat like a telephone. There, sound waves are changed to varying electric currents and these are changed back to sound waves in the receiver.

If you toss a stone into water, circles of waves start and travel in all directions. The farther out they go, the smaller the waves become. If you use a small stone, the waves will be small, but a large stone will produce large waves. The distance from the top of one wave to the top of the next is the *wave length.* The height of a wave is its *amplitude.*

Now if you drop a cork in these waves, you can count how many times it bobs up and down in one second. This is *wave frequency.* The longer the waves, the lower their frequency.

Radio waves have higher frequencies than sound waves. Sound waves range from 16 to 20,000 vibrations per second. But the lowest frequency of standard broadcasting radio waves is 550,000 vibrations per second. It is these very short radio waves that travel long distances through space.

When a program is broadcast, the sound vibrations enter the microphone. The microphone is a special kind of telephone transmitter built in much the same way. Here, the sound vibrations cause an electric current to vary at the same rate as the vibrations enter.

This rate of vibration is called the *audio frequency.* It is usually less than 20,000 vibrations per second. The voltage of this fluctuating current is now increased by means of an *audio amplifier,* which contains a series of vacuum tubes.

After the audio frequency has been amplified, it is combined with the carrier frequency. The *carrier frequency* is the radio wave that will carry the message through space. It has a high frequency and is generated at the sending point. This means that the sound vibrations in the microphone are finally changed into corresponding vibrations in the carrier wave. The carrier waves travel through space from their origin to where they are received. The carrier waves in radio take the place of the wires in telephones.

The receiver takes the radio waves and produces sound again. When the radio waves reach an antenna, they cut

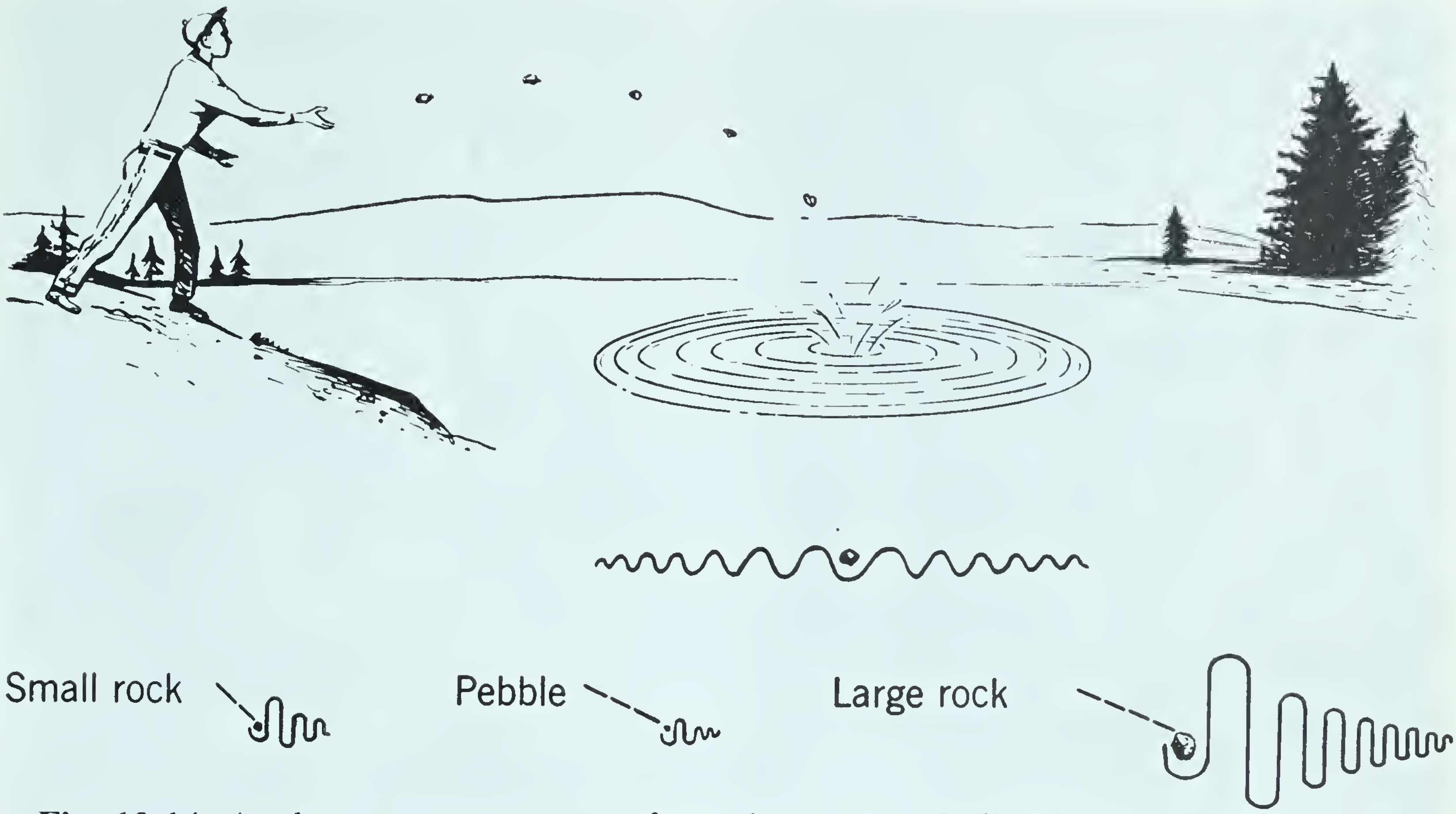


Fig. 12-14. As the waves move away from the source of vibration, the amplitude decreases.

back and forth across it. This produces a weak alternating current in the antenna.

The receiving set is built to catch the weak current, to amplify it, and to be tuned to the frequency of the incoming wave. Each broadcasting station sends out waves of a certain frequency. The receiving set has a dial which permits tuning to the waves of different frequencies.

Radio waves picked up by the antenna are so weak that vacuum tubes are used to make them stronger. In the receiver, the weak waves coming in control the flow of a strong current from the house circuit or from a B battery. As the incoming current varies in strength, the current from the house circuit or from a B battery will also vary in strength. The ***vacuum tube*** acts as a valve to control the flow of current from the circuit. A new device, the ***transistor,*** is now being used to replace the vacuum tubes in many radios, hearing aids, and other types of electronic equipment.

The current from the house circuit or from a B battery, varying in agreement with the original sounds, now goes into the loud-speaker. The current varies the field of an electromagnet and makes a small disk vibrate. The vibrating disk sets up the sound waves you hear. The radio speaker is similar to the telephone receiver.

Some radio waves do not travel as far as others. We have learned that radio waves used for standard broadcasting can travel long distances. These are the ones used for regular radio, called ***AM radio*** (amplitude modulation broadcasting). But the waves used for ***FM radio*** (frequency modulation broadcasting) and for TV cannot go through space as far. Let us see why.

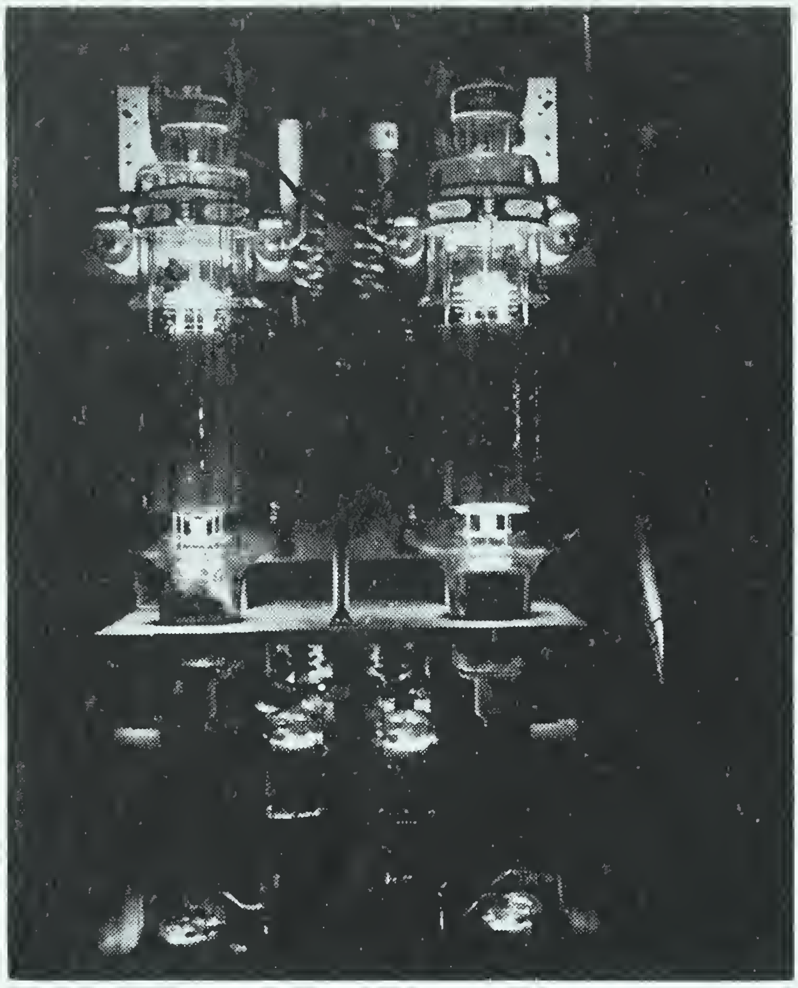


Fig. 12-15. These amplifier tubes are used in radio telephone circuits in transmitting messages from Europe, South America, and some points in the West Indies to Lawrenceville, New Jersey.

Radio waves leaving the antenna at the sending point go out in all directions. Some of these waves follow the curve of the earth and we call them *ground waves.* These give you the best reception on your radio. Others travel up into the sky from the antenna and are called *sky waves.*

During the day, many of the sky waves that go up into the air are lost in outer space. But at night, certain layers of the atmosphere reflect the sky waves back to earth. These are called *ionosphere* (eye-*on*-oh-sfere) *layers.*

The ionosphere layers and the earth act like mirrors for the sky waves. The waves hit the ionosphere and are reflected back to earth. Then the earth reflects the waves and sends them back

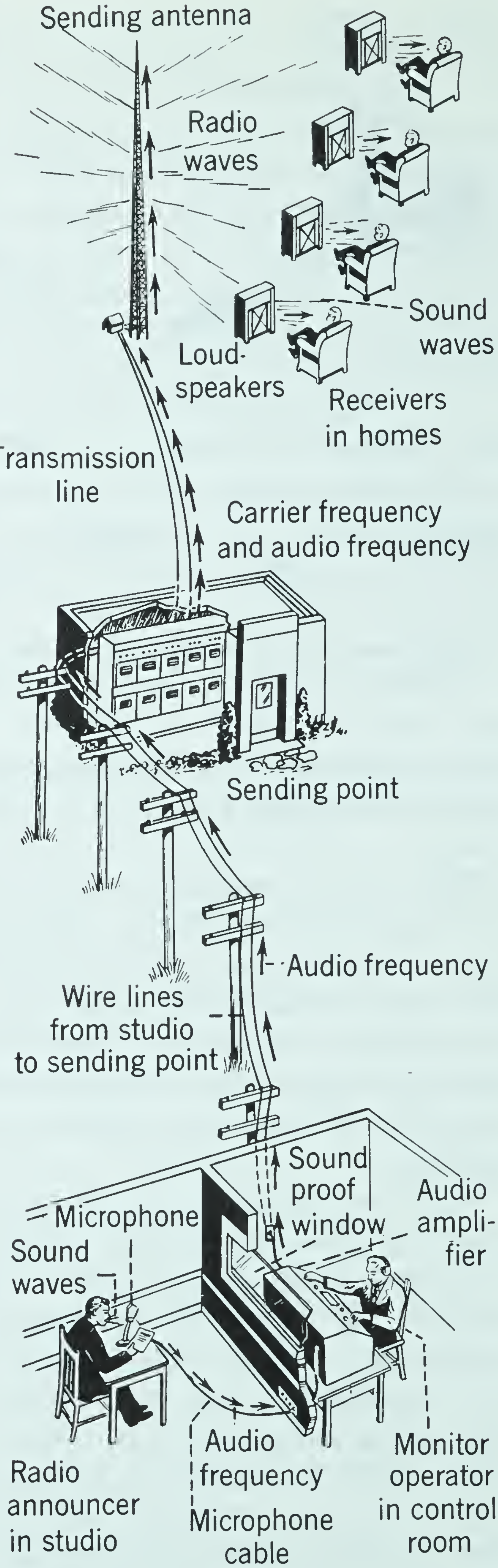


Fig. 12-16. This diagram shows an AM broadcasting system. The waves used for AM broadcasting can travel long distances.

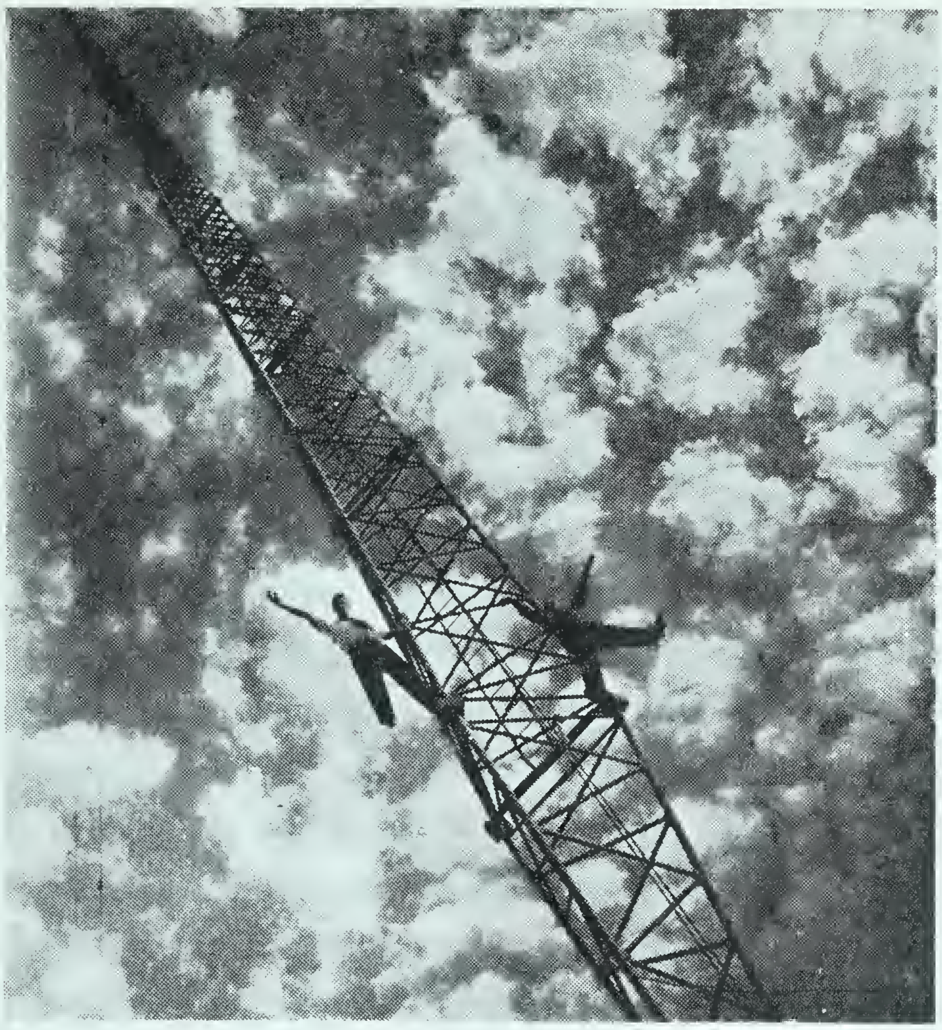


Fig. 12-17. From radio towers such as this, radio waves are transmitted for thousands of miles.

up to be reflected by the ionosphere again. This sometimes continues until the radio waves have gone thousands of miles. Now can you explain why you can hear certain distant radio stations only at night?

To get good reception on FM and TV sets you must live near the station. What we have just learned about sky waves does not hold for certain high frequency radio waves used for FM and TV. Your family may own one of these sets. If so, you know you cannot get steady reception if you live much beyond 50 miles from the station, unless there is some sort of relay to carry the station signals farther. This is because only the ground waves are use-

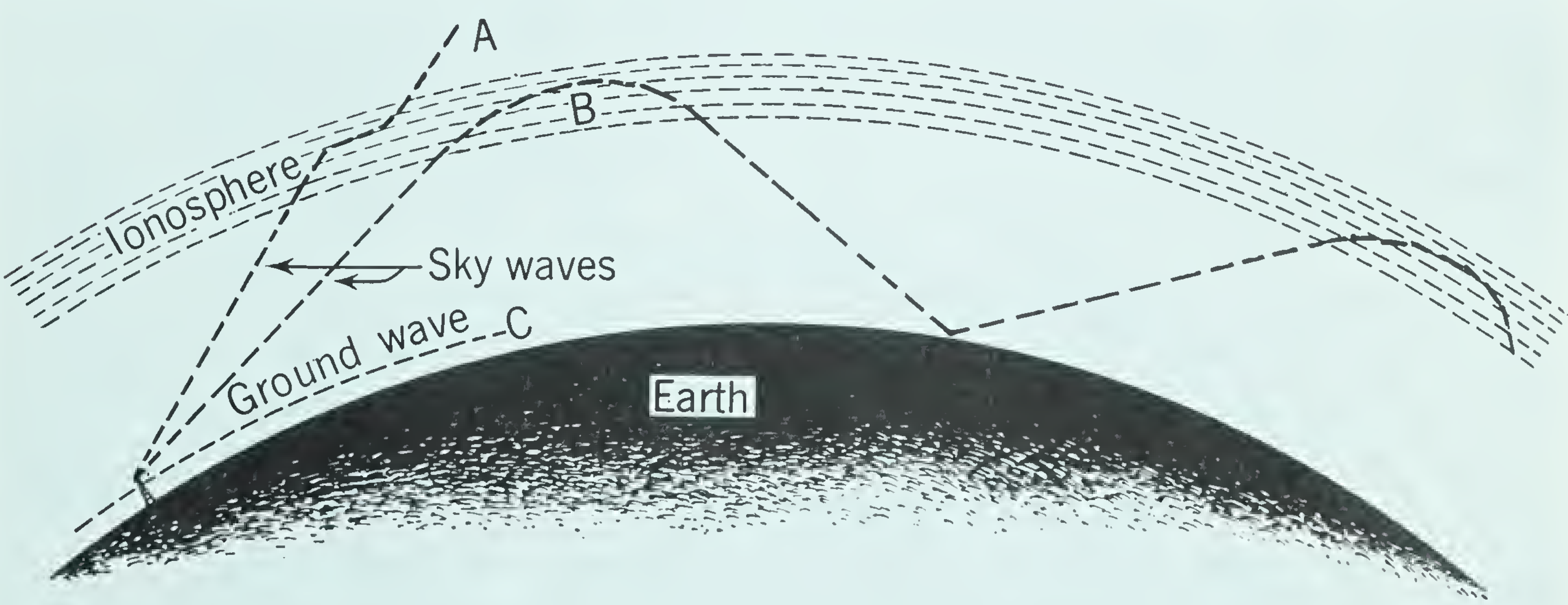


Fig. 12-18. From this diagram, you can see how radio waves travel as ground and sky waves. During the day, sky wave A goes right up through the clouds. At night, B is reflected back to earth. C gives the steadiest reception.

ful at higher frequencies. The sky waves go right through the ionosphere without being reflected back to earth. So the station can only send waves to the horizon, which is about 50 miles if no hills or large buildings are in the way. It is important to remember this if you plan on getting an FM radio or TV set and live far away from stations.

REVIEW QUESTIONS

1. How are sound waves changed into electrical waves to be sent through the air? **2.** How are electrical waves changed back into sound waves? **3.** For what is the vacuum tube used? **4.** Explain how loud-speakers operate. **5.** What do the ionosphere layers do to standard radio waves? **6.** Why do you get poor reception on FM or TV sets if you live beyond 50 miles from the stations? **7.** How does a microphone operate? **8.** What is the function of the antenna in a radio receiving set? **9.** How would you distinguish between ground waves and sky waves?

E How does television bring events into your home?

Television is a triumph of scientific discovery and progress. You know how long it takes before you can see newsreel pictures in your local movie house. The pictures have to be developed and the reels sent to the theater. By the time you see the events, they may be several days old. In television broadcasting, you can see the event in your home almost as soon as it happens.

In TV broadcasting, the sound and the picture are sent out instantly by two quite different radio systems. Your television receiver set has radio equipment to pick up both the picture and the sound.

All this did not just happen. Television has been known for a good many years, but it was not perfected for home use until after World War II. After the discovery of television, scientists spent much time trying to make it practical so that it could be enjoyed in every home. As a result of that discovery and the scientific progress which took place, you can now sit down in your easy chair and see a program of news, or a sports event, or an entertainment.

The camera tube takes the picture. The most important part of the television camera is the *camera tube*. It may be an ***iconoscope*** (eye-*kon*-oh-skope), an ***orthicon*** (*orth*-ih-kon), or an ***image orthicon.*** Cameras all have one of these, depending on the subject being photographed and the intensity of the light. The image orthicon is a new development and is good for taking pictures when the illumination is poor.

A series of lenses focuses light from the object on a plate inside the camera tube. The surface of this plate consists of thousands of light-sensitive particles. These act like photoelectric cells. A ***photoelectric cell*** is a device which produces a change in an electric current when the light which strikes the cell changes in intensity.

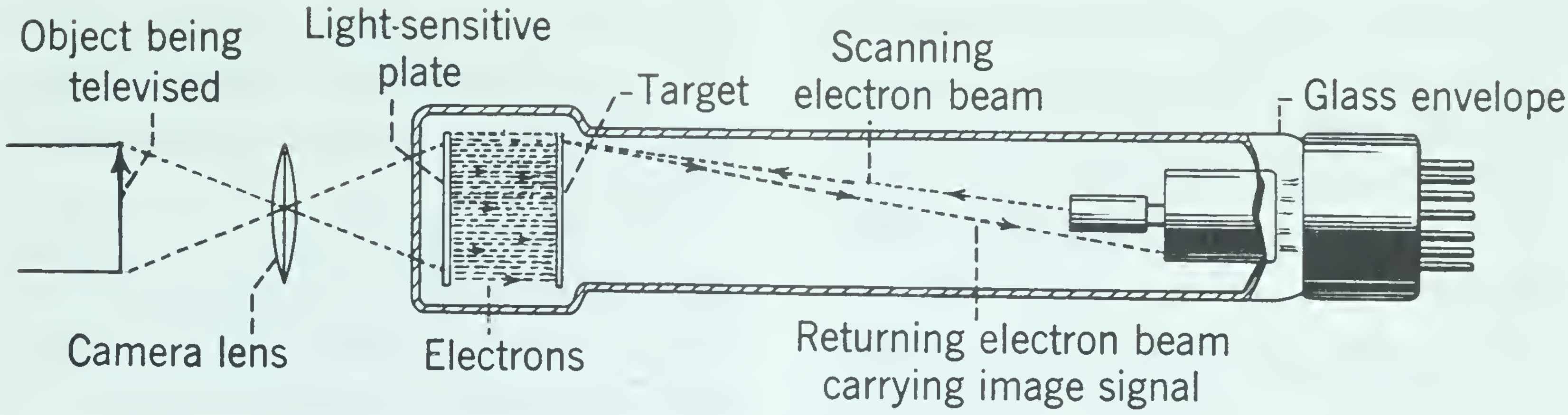


Fig. 12-19. This diagram explains the operation of the image orthicon, a new development of the television camera tube.

PUPIL ACTIVITY

Obtain a photographic light meter (see Fig. 9-44). Light a candle and darken the room as much as possible. Starting about six feet from the lighted candle, slowly move the light meter toward the candle. What change do you see in the reading of the light meter?

The light meter contains a photoelectric cell which reacts by producing a varying electric current depending on the intensity of the light that strikes it. What other uses of photoelectric cells can you find?

The thousands of light sensitive particles in the television camera tube are actually photoelectric cells. Each photoelectric cell gives off electrons in proportion to the amount of light shining on it. On spots where the light is brightest, many electrons are given off.

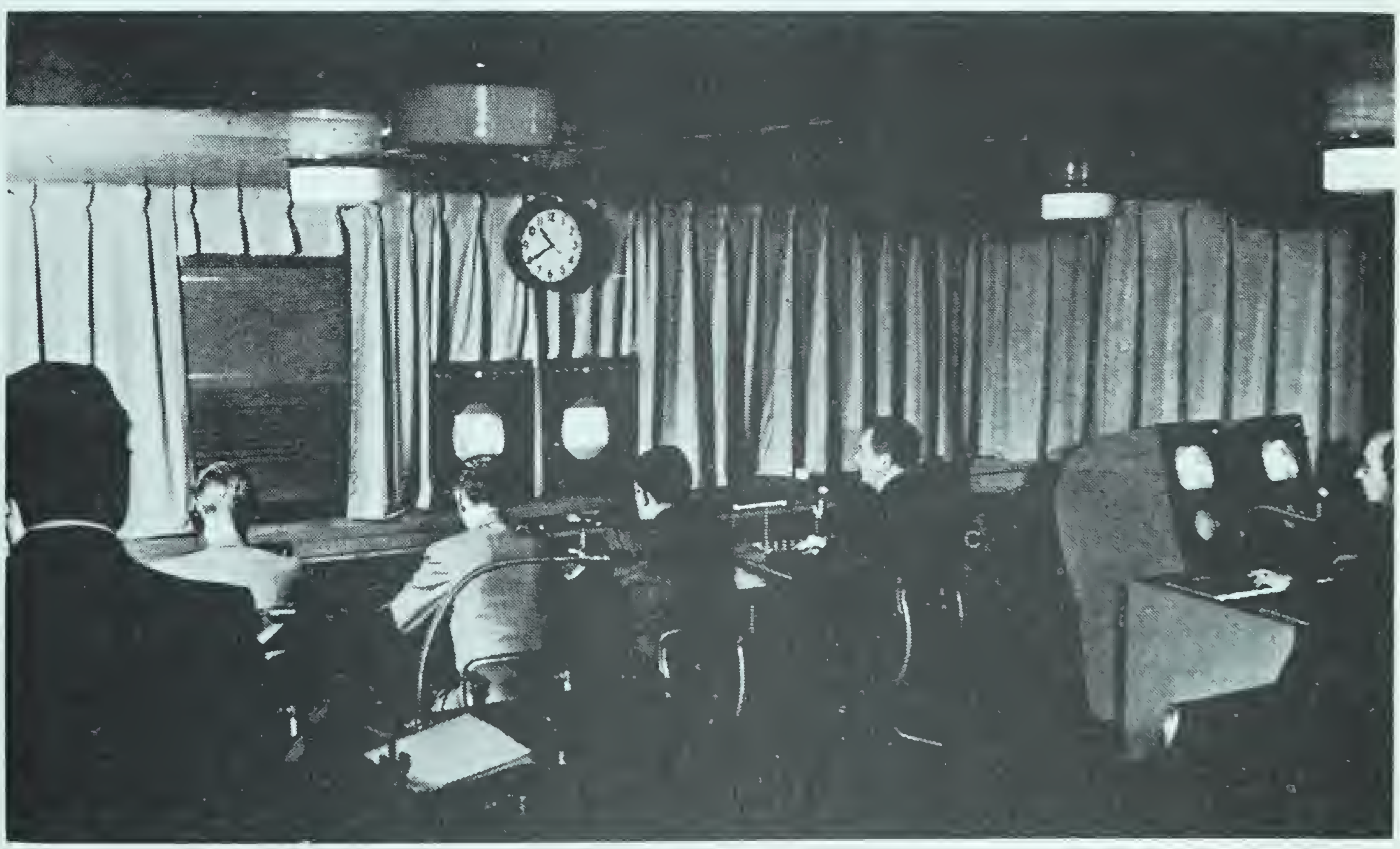


Fig. 12-20. This photograph takes you inside the control room of a television station.

Where the light is dim, few electrons are given off. This actually forms an electron picture on the plate, with the greatest electron charge where the light is brightest. The electrons given off by the plate flow to the target (see Fig. 12-19). Here they produce an electrical "picture."

A pencil-like beam of electrons moves back and forth in 525 horizontal lines across the target. This is known as *scanning.* The beam scans the target 30 times a second. Thus the beam moves back and forth 15,750 times a second. This is done so rapidly in order to prevent flickering.

When the electron beam hits a spot on the target where electrons have been given off due to light, it causes a fluctuation in the current. Thus the lighter and darker spots produce changes in an electric current.

This fluctuating current modulates the carrier wave as in regular AM radio broadcasting. This wave then goes out to television receivers in the vicinity.

Television receivers pick up both the picture and the sound waves. When these waves cut a television antenna, they set up a weak current. This is the same as in a radio antenna. After the current has been amplified, it is fed into the *picture tube.* This is the heart of the receiver just as the camera tube is the heart of the television camera.

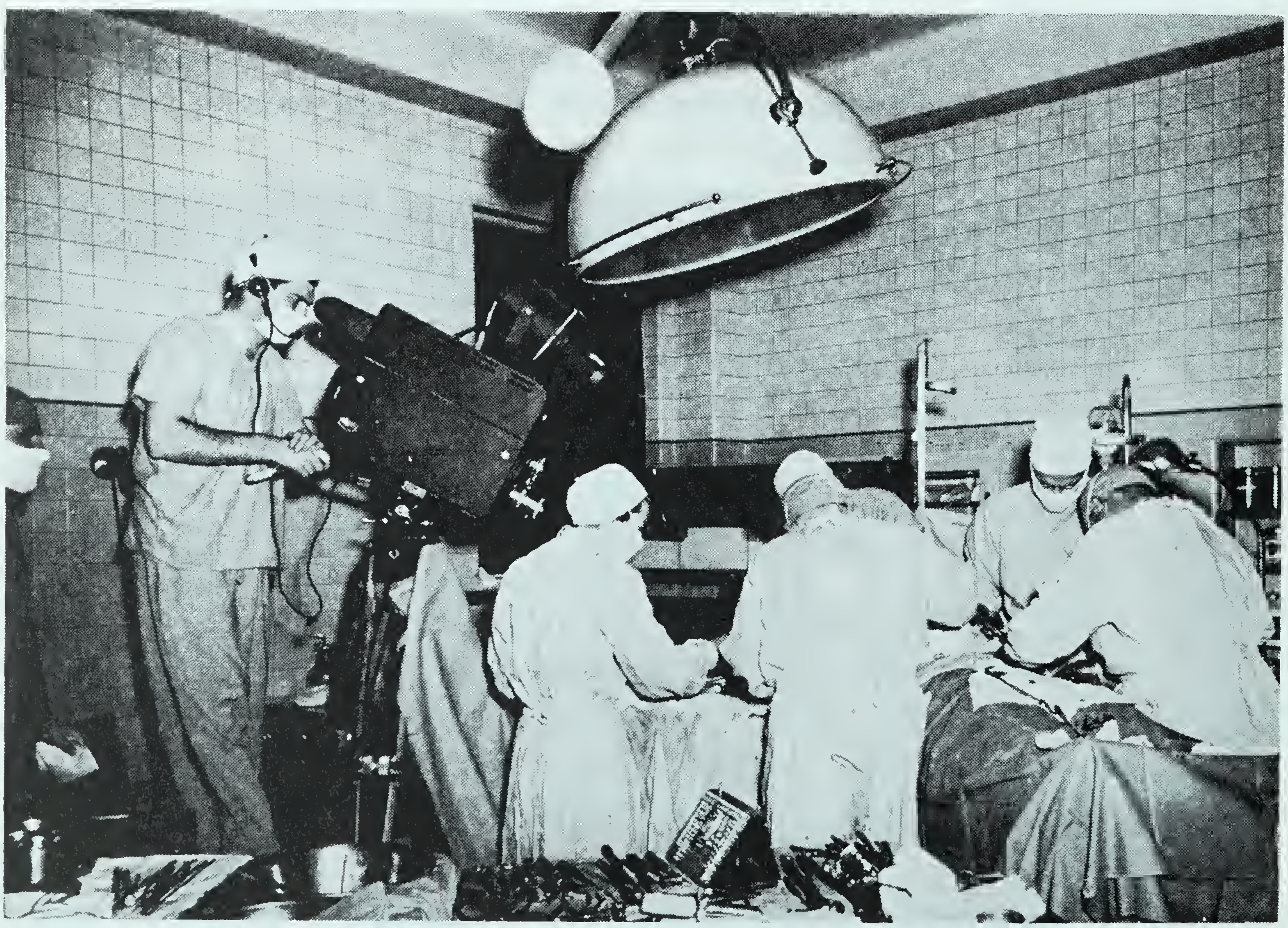


Fig. 12-21. A television camera in a hospital operating room gives medical students an opportunity to see the operation on color receivers in another room.

The picture tube also has an electron beam in it. This beam scans the screen of the picture tube in the same way the beam scans the target in the camera tube.

The screen is coated just like the inside of a fluorescent lamp. When the electron beam hits it, the screen lights up for an instant. This happens just at the spot where the beam hits.

The amount of light on the screen depends on how strong the beam is at that moment. Remember that the impression of the picture sent out by the television station depended on the light that first hit the photoelectric cells. Now this impression controls the amount of light that will appear on the screen. That is how the impressions of dark and light are formed.

Color television is similar in principle to black and white television. It requires three orthicon tubes in each camera for transmission. Receivers for color television are more expensive because they must have additional special circuits and tubes, including the large picture tube.

The terrific speed at which the electron beam scans the fluorescent surface of the screen gives you the impression of a complete picture. But you understand that actually the screen is lit up in a series of dots and lines. The sound portion of a television broadcast is sent and received as ordinary FM radio waves.

REVIEW QUESTIONS

1. What is the heart of the television camera? How does it work? **2.** What is the advantage of the image orthicon type of camera tube? **3.** What prevents flickering on the television picture you see? **4.** How does the picture tube of the receiving set work?

F How are different radio frequencies used in industry and transportation?

Many different radio frequencies are used in broadcasting. Standard AM radio, FM radio, and television operate at different radio frequencies. There are other ways in which to use radio waves in industry and military and naval operations.

Television is used to watch surgical operations in hospitals, to see certain industrial processes, and even to observe atomic explosions. Some of these are not sent through the air by radio. Instead, the impressions may be sent over wires in a closed circuit like telephone calls. But radio frequencies are still used to carry the messages from sending point to receiver.

Radar is in the group of shortest radio waves we use. These waves are called *microwaves* since their wave lengths are so short. We use radar to locate planes, ships, buildings, land, and other objects. Its name comes from the words *Radio Detection and Ranging.*

One of the important qualities of radio waves is that they reflect from various solid objects much as light does. What a radar set does is to send

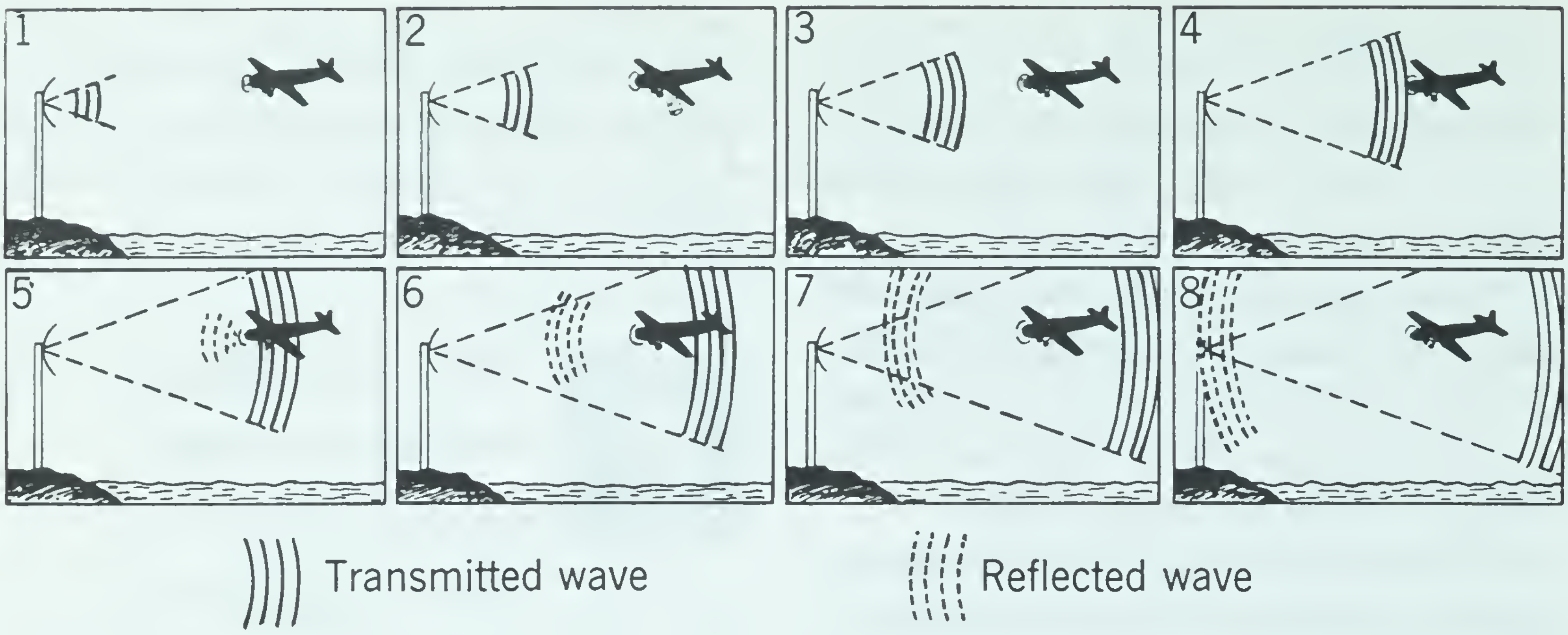


Fig. 12-22. This diagram shows the various steps in spotting an approaching airplane by radar.

out radio waves. Then, when some of them are reflected back, the set records the amount of time it took the waves to go out and return. Radio waves travel at 186,000 miles a second. A single antenna sends out the microwaves and also receives the reflected waves. Complex instruments use the time interval to calculate the distance of the object.

The reflected radar waves can be used to trace a picture on a fluorescent screen. This screen is like the one in a television picture tube. You can look at the screen and tell at a glance what objects are near you.

Fig. 12-23. This radar installation is used to detect the advance of distant airplanes. The one flying above the radar tower here is an interceptor plane.

Radar is used for navigating ships and planes. Since radar can locate an object even in darkness, fog, or storms, it is widely used on ships and airplanes. Radar installations are used at airports when the visibility is poor. By this means, aircraft can be located exactly and guided safely down to the runways, even in the thickest fog.

What we have learned in this unit is only an introduction to the fascinating field of science dealing with electrons, known as *electronics* (ee-leck-*tron*-icks).

REVIEW QUESTIONS

1. What are some other uses for television besides entertainment? **2.** Which radio waves are used for radar? **3.** What does the radar antenna do? **4.** Name some uses for radar.

QUESTIONS FOR REVIEW AND DISCUSSION

1. What are the difficulties of sending sounds over long distances?
2. Under what conditions can signaling by light be used?
3. How was the telegraph developed?
4. What is the history of the development of the telephone?
5. What men have worked on, and contributed to, wireless telegraphy and radio?
6. How are signals sent over a telegraph wire?
7. How does a telegraph sounder differ from an electric bell?
8. What is the Morse Code?
9. What is an induced current?
10. What are the essential parts of a generator? How is the current produced?
11. What is the purpose of a commutator on a generator?
12. What are the parts of a telephone?
13. Explain how sounds are sent over a telephone system.
14. In what part of the telephone system are sound waves changed to electrical waves? Where are the electrical waves changed back to sound waves?
15. Compare the velocities of light, sound, and an electric current.
16. How are signals sent by wireless telegraphy?
17. How are messages sent and received by radio?
18. What is wave length? Compare the wave lengths of light, sound, and radio.
19. Why is it necessary for each broadcasting station to operate on a set frequency?
20. Explain how a radio receiver changes electrical waves to sound waves.
21. What is the amplitude of a wave? What are sound amplifiers?
22. What are the uses of the photoelectric cell, image orthicon, and picture tube in television broadcasting?

23. What are the advantages of television broadcasting over radio and motion pictures? What are the disadvantages?

24. What are radar waves? How is an object located by radar? How is the distance of an object from the radar set measured?

25. Why is it necessary to use high frequency waves in sending messages by radio?

26. What are the different ways in which induced currents can be produced? How is an induced current produced in the secondary circuit of a telephone system?

27. In the field of communications, what scientific inventions have been made since the first message sent by telegraph up to the present system of television broadcasting? Assume that the electromagnet made the telegraph possible.

28. What is the advantage of having high radio and television transmitting towers? Consider the curvature of the earth.

29. What is sent over wires or through space in each of these: (a) telegraph; (b) telephone; (c) wireless telegraph; (d) radio; (e) television; (f) radar?

SPECIAL REPORTS AND PROBLEMS

1. Construct and operate a telegraph key and sounder.

2. Construct and operate a simple crystal radio receiving set.

3. Set up a simple telegraph system. Practice until you are able to send and receive short messages.

4. Visit one of the following and report on what you see: a power station, a telephone exchange, a radio station, a television station.

5. What have the following men contributed to the development of electricity: Oersted, Faraday, Morse, Bell, Marconi, and Edison?

6. Report on the uses of vacuum tubes.

7. Report on the uses of radar.

8. Report on the uses of television.

TESTING THE PURPOSES OF THIS UNIT

1. Define and give the meaning of each of the following words or terms: antenna, iconoscope, audio frequency, induced current, microphone, photoelectric cell, radar, telegraph relay, radio frequency, television, wave frequency, carrier frequency, vacuum tube, generator, aerial, AM radio, FM radio, microwaves, electronics, loud-speaker, ground waves, sky waves.

2. What developments have followed from the invention of the electromagnet? Consider the electric bell, telegraph, telephone, motors, generators, gasoline engines, automobiles, airplanes, radio, television, radar.

3. Why was it necessary to have a knowledge of the characteristics of sound waves before the telephone could be invented and improved?

4. In what different ways is electrical energy used in a modern home?

5. Discuss the contributions of electricity to modern civilization.

The old

OF ALL DEVELOPMENTS IN SCIENCE, NONE IS MORE WONDERful than those which have improved our means of communication. In early times, signals were made with fires or with flags and banners, but they were used only for short distances and under favorable conditions. Such signals required a special code in order to be understood.

When the Erie Canal was opened in 1825, the information that a boat had started to pass through the canal was sent to people at the other end by firing in succession cannons placed at equal distances from one another along the way.

The new

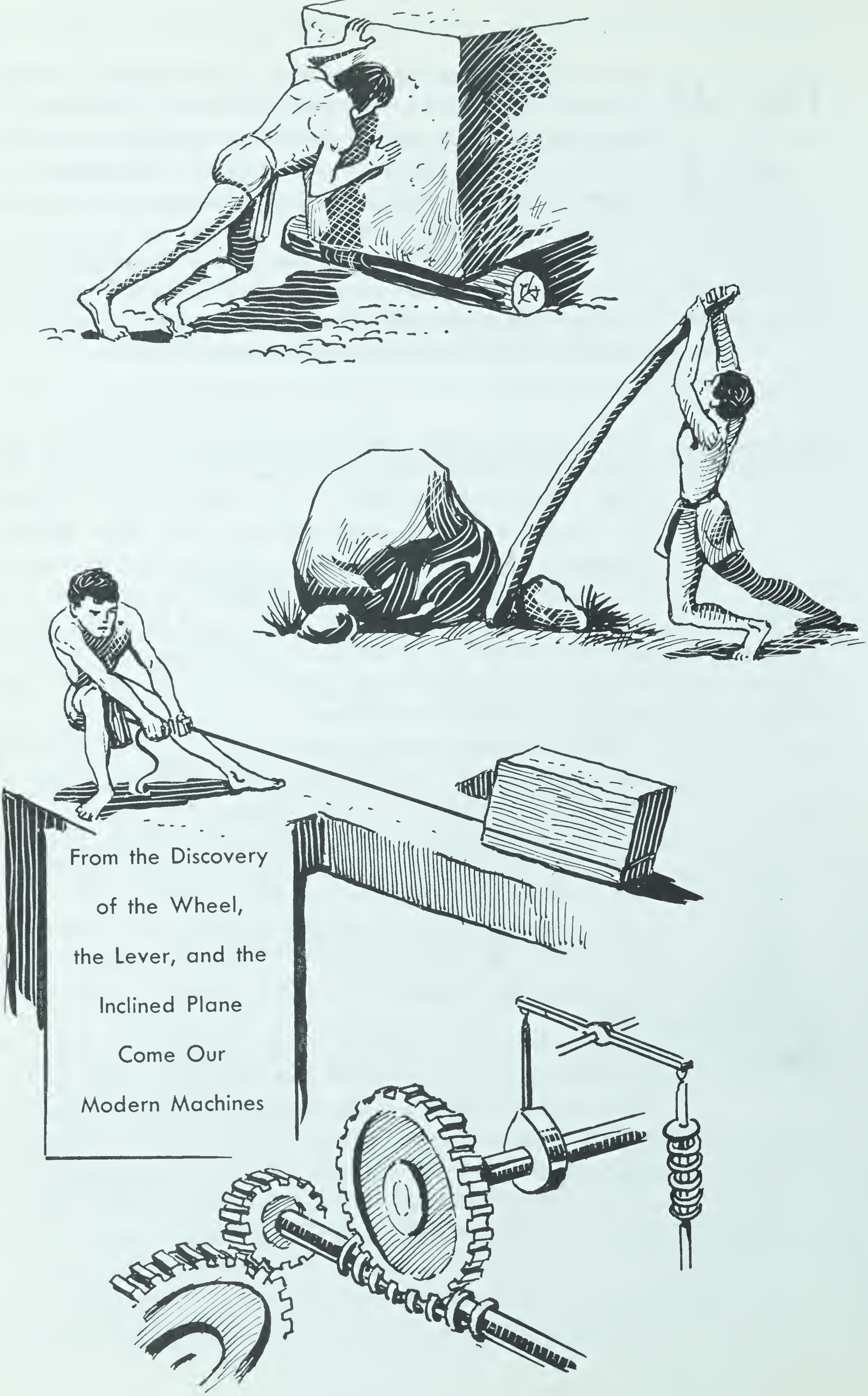
WITH THE DISCOVERY OF THE RELATIONSHIP BETWEEN MAGnetism and electricity in 1819, the electromagnet was invented. Then followed the invention of the telegraph, the telephone, the wireless telegraph, radio, television, and radar. Messages can now be sent to all parts of the world in a few seconds, and we can get reports of important events at the same time they occur. Even pictures are sent by wire and by radio. We can now take pictures of some event on the Pacific coast and within one hour these pictures are received on the Atlantic coast, ready for use in the newspaper.

With television, pictures and sound are now sent instantly to all parts of the United States. Color television is here and will be further improved in the coming years.

Radar is necessary to detect and locate planes, ships, and other objects. It has many practical uses which will make it just as important in the future as improvements occur.

The transistor may well replace vacuum tubes in the future. It is smaller and more rugged in construction. Transistors also last longer than vacuum tubes, and consume far less electric power.

We must never overlook those scientists on whose discoveries our modern inventors depend for basic theories. Consider the improvements in our methods of living brought about by the work of Oersted, Henry, Faraday, Volta, Morse, Bell, Marconi, and Edison. To these, we must also add the names of modern scientists and inventors who are constantly improving our present methods of communications.


From the Discovery
of the Wheel,
the Lever, and the
Inclined Plane
Come Our
Modern Machines

UNIT 13

How has man learned to use machines to help him do work?

DISCOVERY AND PROGRESS

MAN used machines long before he wrote history. Our museums contain many ancient tools which have been preserved through the centuries. In fact, man's superiority over animals has depended greatly on his ability to make and use tools.

The first tools man used were probably intended for defense. Doubtless, the first weapon he ever made was a club. Later, when he fastened a stone

to it to make the end heavier and more deadly, he had a tomahawk. Then he added a handle to a stone which had been sharpened on both sides by chipping, and made an axe.

Man may have made a spear by fastening a long branch to a sharpened stone. He probably discovered the principle of the bow in seeing bushes and small trees snap back to shape after pulling them down to gather fruit. With a bow and arrow, man could throw his sharp spears farther. He then had a real weapon for both getting food and defending himself.

Man used his club not only to strike his enemies but also to batter down trees and move big stones. Here we have his discovery of the *lever*. The axe, used to cut down trees, led the way to discovering the *wedge*. Then the wedge was enlarged and formed the *inclined plane*. When man learned how to curve the inclined plane, he made the *screw*. The lever, wedge, inclined plane, and the screw are *simple machines* and we use all of them today. This is how progress is made; one simple invention leads to another.

No one knows how or when the *wheel* was first invented. Perhaps early man watched a rounded stone roll down a hill. Or, he may have found that he could use the trunk of a small tree to help him roll a heavy object. Perhaps the roller came first and then the wheel. Later, he used the wheel as a *pulley* to help lift heavy objects. History tells us that the Egyptians used the wheel and the inclined plane to move those huge blocks of stone to build the pyramids. They also used it to raise water from the Nile River to nearby land so they could irrigate their fields.

Later, paddles were added to the wheel and the force of running water was used for power. The invention of the wheel was the beginning of modern transportation. Today we find it in almost every machine we use.

At first man operated his machines by his own energy. When he had tamed some animals, he used them to help him. As the years went by he used running water, fuels, and finally electricity. As new forms of energy were discovered, he made new machines to help use this energy. But we must remember that as long as man was satisfied to know *how* machines were operated without asking *why*, progress was slow. Man had developed skill in using tools, but he did not understand the science of machines. Real progress did not come until he began to find out why machines operated as they did.

We must give Archimedes (ar-kih-*mee*-deez) credit for introducing *mechanics* as a science. He said: "Equal weights acting at equal distances on opposite sides of a pivot are in equilibrium." You used this principle as a child when you balanced with a friend on a see-saw. Archimedes' understanding of the value of the lever is well expressed in another famous quotation: "Give me a fulcrum on which to rest a lever, and I will move the world." He showed how to move heavy ships with pulleys, and he invented the endless screw, using it to drain the holds of ships.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What is force and how do we measure it? **2.** What is work and how is it measured? **3.** What is power? What are the different units of power? **4.** What is a machine? **5.** How is the principle of work applied in machines? **6.** For what purposes are machines used? **7.** What are levers and how are they used? **8.** How are the inclined plane, wedge, and screw used to do work? **9.** How can forces be transferred from one wheel to another? **10.** How efficient are machines? **11.** How is friction overcome in machines? **12.** What machines are used in your home?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

compound machine . a combination of two or more simple machines used for some special purpose.

foot pound .... a unit of work. The work done in lifting a weight of one pound a distance of one foot.

fulcrum .... (*full*-krum), the point or support about which a lever turns.

horsepower .... 550 foot pounds of work per second, or 33,000 foot pounds per minute.

lever .... a simple machine consisting of a rigid bar which is free to turn about a fixed point called the fulcrum.

machine .... any mechanical device man uses to help him to do work.

power .... the time rate of doing work.

pulley .... a simple machine consisting of a small wheel with a rim, mounted on a frame in such a way that it can turn easily on a fixed axle.

resistance .... the object to be moved, or the object against which force is applied.

work .... a force acting through a distance.

A What is work and how is it measured?

We use force and energy to do work. A *force* is a push or a pull. We can measure the strength or quantity of a force with a spring balance. If you want to lift an object, you exert a force to do it. Your force overcomes the force of gravity. Gravity, you see, tends to hold the object on the ground. You also know that gravity is a force.

Energy is the ability to do work. You know that the energy of running water, wind, and moving objects is ***kinetic*** (kin-*et*-ick) ***energy.*** But what about the kind of energy that is stored in coal, gas, oil, and other fuels? This is ***potential*** (poh-*ten*-shall) ***energy,*** or stored energy. Water behind a dam has potential energy, but when it falls, its energy is changed to kinetic energy.

Work is the product of the force acting and the distance it moves. What do you mean when you say you have done some work? It may mean one of many things. In the study of machines, work has a definite meaning. If you lift an object off the ground, you are doing work. If you pull something up a hill, you are also doing work. And if you raise a five-pound weight a certain distance, you have done a definite amount of work.

If you exert all your strength trying

Fig. 13-1. By lifting the box of groceries to his shoulder, this boy has done work.

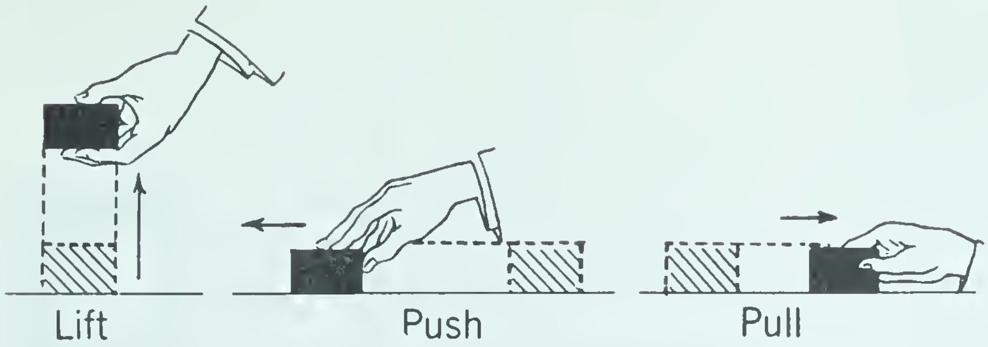


Fig. 13-2. Force is required to do work. To lift the brick, more work is done than when it is pushed or pulled.

to lift an object but find you cannot move it, you actually do no work—in a scientific sense. You have exerted a force but you have done no work. To do work, you must exert a force through some distance.

A unit for measuring work is the foot pound. In measuring work, we must know how much force is exerted, and the distance it moves. If a weight of one pound is raised one foot, one *foot pound* of work is done.

Work equals force times distance, or using a formula, $W = F \times S$. W stands for work, F for force, and S for distance. If a boy weighs 100 pounds and he walks up a flight of stairs 20 feet high, he has done 2,000 foot pounds of work. Substituting in the formula, we get $100 \times 20 = 2{,}000$.

The amount of work done in moving an object a certain distance is not affected by the time it takes to do it. It may be moved slowly or rapidly. The force and distance do not change; consequently, the product of the two does not change.

DEMONSTRATION

Lift a brick with a spring balance. How much work is done in lifting the brick four feet? Pull the brick along a table. What force is needed to move the brick? How much work is done in sliding the brick four feet?

More work is done when a resistance is lifted *up* than when it is moved *along* a surface. When some object is raised, it can be in a position to give back the work when it falls. If some object is moved along a level table top, some force is required. This force acts

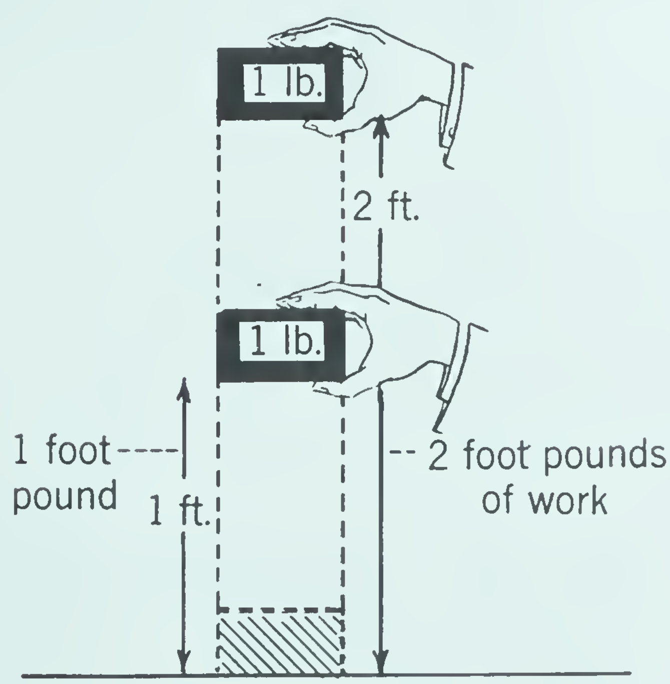


Fig. 13-3. A foot pound is a unit of work. It is the work done in lifting a resistance of one pound a distance of one foot.

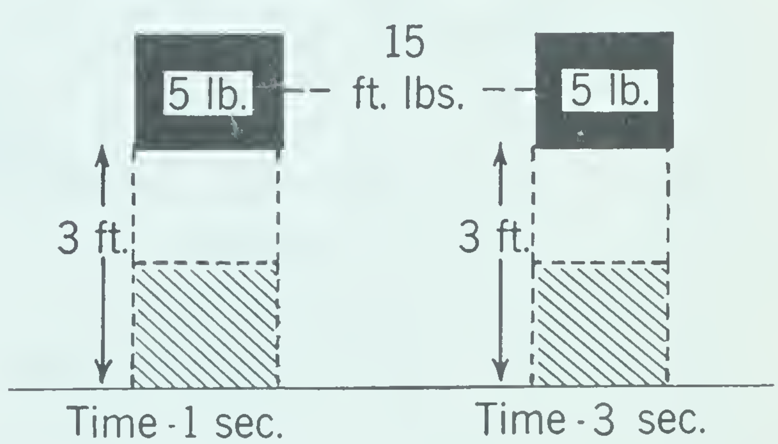


Fig. 13-4. The amount of work done in moving an object is independent of the time taken to do it.

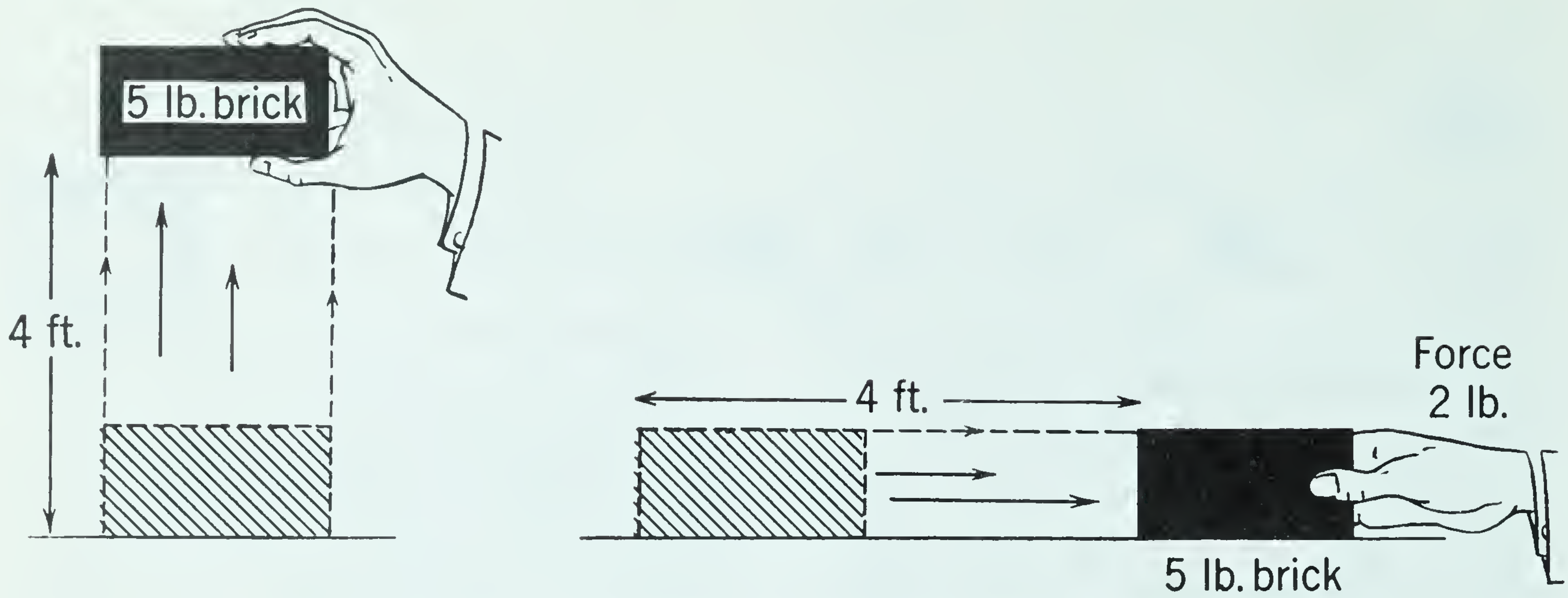


Fig. 13-5. Why does it require more work to lift this brick four feet than to pull it the same distance?

through some distance. Some of the energy used in doing this work is changed to heat.

Power is the speed or rate of doing work. Suppose a boy weighs 100 pounds. He runs up a flight of stairs 20 feet high in half the time a friend weighing the same does. Then he works at twice the *power* his friend does, although they both do the same amount of *work*. But he has, of course, done the work in less time.

In measuring power, you must know the force exerted, the distance it moves, and the time during which the force acts, in seconds or minutes.

A horsepower is a unit of power. If a machine does work at the rate of 550 foot pounds per second, the power at which it works is one horsepower. By definition, one *horsepower* is 550 foot pounds of work per second. This is 33,000 foot pounds per minute.

If a weight of 550 pounds is raised 8 feet in 2 seconds, at what rate is work being done?

$$\textit{Horsepower} = \frac{550 \times 8}{2 \times 550} = 4$$

REVIEW QUESTIONS

1. What is a force? **2.** What is energy? What are the two kinds of energy? **3.** What is work? **4.** What is power? **5.** How much work is done when a cubic foot of water is raised 10 feet? **6.** What is the horsepower needed to do 3,300 foot pounds of work in 3 seconds?

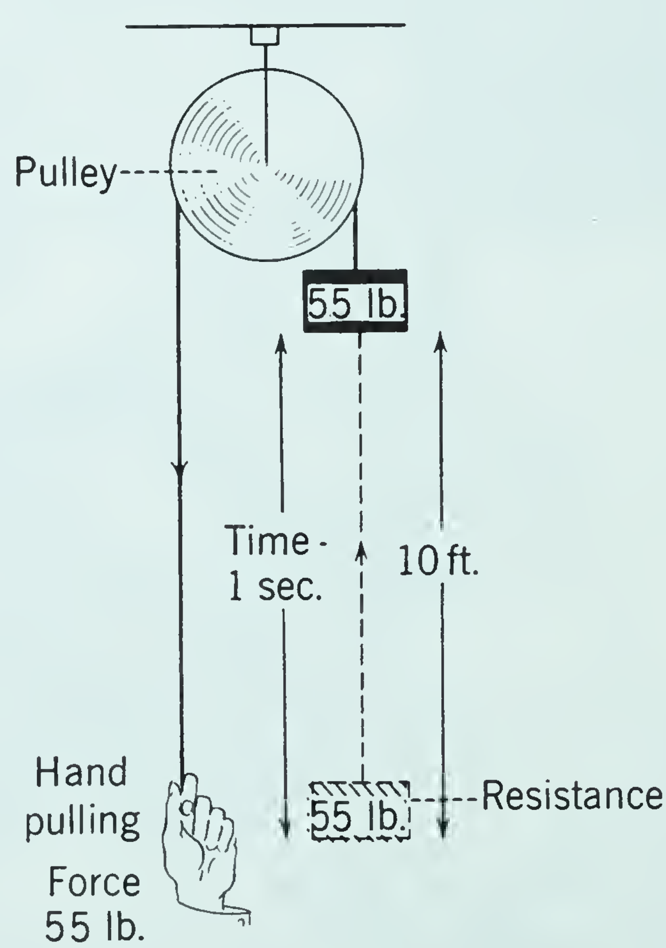


Fig. 13-6. Work is being done here at the rate of one horsepower.

B What are machines and what do they do?

A machine is a mechanical device man uses to help him do work. Work is calculated by multiplying a force times a distance. A force that lifts a 10 pound object to a height of 10 feet accomplishes 100 foot pounds of work. The same amount of work would be done in lifting a 20 pound weight to a height of 5 feet.

Let us illustrate this. An object weighing 20 pounds is raised 1 foot. The work done is 20 foot pounds. If you use a machine, it is possible to lift the 20-pound object by using a force less than 20 pounds. If a smaller force is used, the distance it moves must be greater because the product of the two remains the same. We can illustrate this by the following problem:

20 lbs. × 1 ft. = 20 foot pounds (without a machine)
10 lbs. × 2 ft. = 20 foot pounds (with a machine)
5 lbs. × 4 ft. = 20 foot pounds (with a machine)

The work done is the same in each case. With the machine, you can do the same amount of work by using a smaller force and making it move through a greater distance. Or, you can use a larger force and make it move a smaller distance.

There is some friction in the operation of all machines. Inertia is also a factor in starting and stopping machines. Friction can be caused by parts moving over each other, or by wearing of rough surfaces, or by some other factors. When the work done on a machine and by a machine are equal, friction has been disregarded.

A machine can do work only after work has been done on it. A machine merely gives back part of the work done on it. Man has never been able to build a machine that will decrease the amount of work to be done.

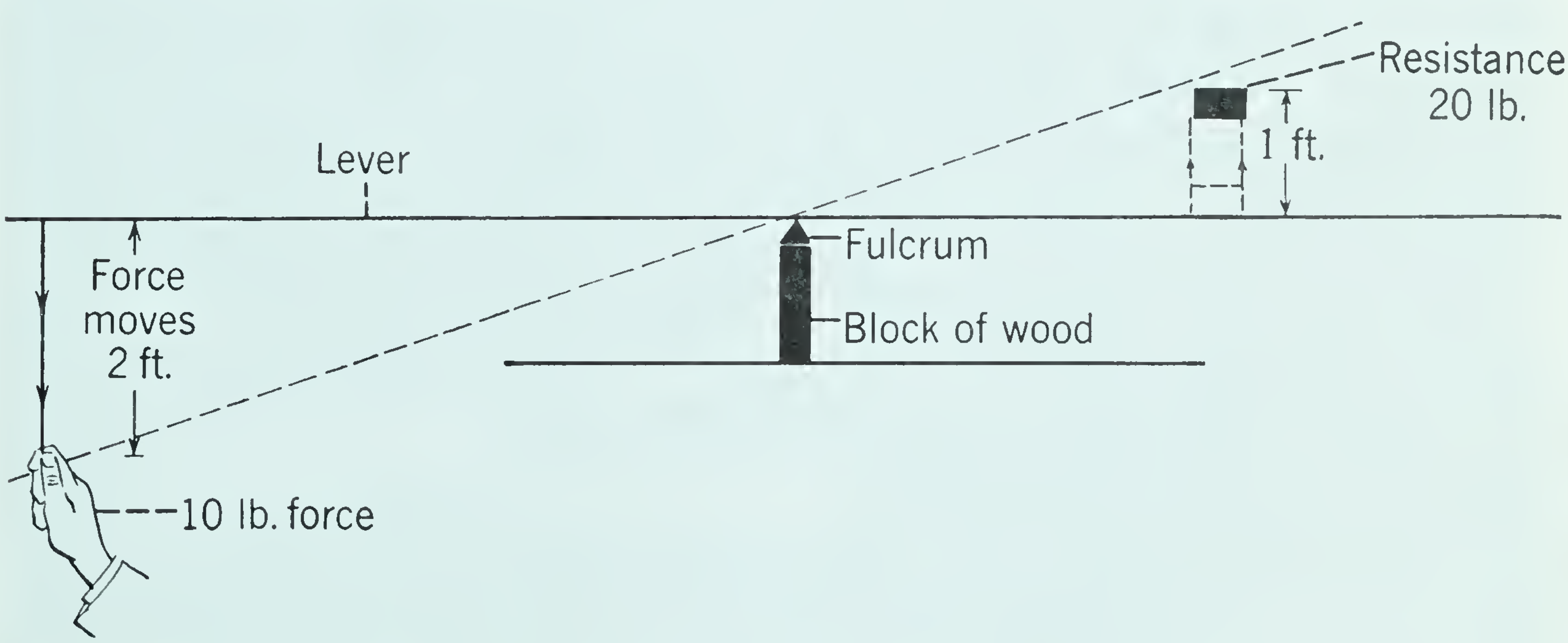


Fig. 13-7. In any machine, disregarding friction, the force times the distance it moves equals the resistance times the distance it moves.

Fig. 13-8. As this boy pushes the lawnmower, he is exerting a force and doing work on the mower.

Some kind of a force must be applied to a machine before it can be used to exert a force to overcome some resistance. A machine does not decrease the amount of work to be done. Actually, more work is done with a machine because of friction and the force needed to operate the machine itself.

Machines are used for three purposes. They are used: *First,* to move heavy objects with small forces. Result: a gain in force. When we use them this way, the force is always less than the weight, or resistance.

Second, to move a weight, or resistance in one direction while the force moves in some other direction. Result: a change in direction.

Third, to use a force so as to overcome the resistance more rapidly. Result: a gain in speed. When we use them this way, the resistance moves at a greater speed and through a greater distance than the acting force. The force is always greater than the resistance overcome.

The work done by a machine is equal to the work done on the machine, if friction is disregarded. The work put into a machine (*input*) is always equal to the work accomplished by the machine (*output*), friction being disregarded.

The force $\times$ distance it moves = resistance $\times$ distance it moves.

$$F \times d = R \times d'$$
$$10 \text{ lbs.} \times 10 \text{ ft.} = 20 \text{ lbs.} \times 5 \text{ ft.}$$
$$100 \text{ foot pounds} = 100 \text{ foot pounds}$$
$$\textit{Input} = \textit{Output}$$

The object to be moved, or against which the force is applied, is called the ***resistance.*** In this case, a resistance of 20 pounds is raised a height of 5 feet by using a force of 10 pounds moving through a distance of 10 feet. The force was one-half as much as the resistance, but it moved twice as far as the resistance. What was gained in force was lost in distance. But in this example, friction was disregarded.

Friction decreases the efficiency of machines. Although friction decreases the machine's efficiency, we could not use the machine if there were no friction. It would be difficult to start or stop it.

The *efficiency* of a machine is that percentage of the work put into the machine which can be taken from the machine as useful work. Efficiency can be calculated by dividing the output of work by the input, and then multiplying by 100 to obtain a percentage, as shown by the following sample problem.

What is the efficiency of a machine if a force of 4 pounds moves 3 feet to raise a resistance of 5 pounds 2 feet?

$$\frac{\textit{Output}}{\textit{Input}} = \frac{R \times d'}{F \times D'} = \frac{5 \times 2}{4 \times 3}$$
$$= \frac{\textit{10 foot pounds}}{\textit{12 foot pounds}} = 83.33\%$$

PUPIL ACTIVITY

(A) A machine was used to lift a 300-pound weight 4 feet. It needed a force of 125 pounds to lift it, and the force moved 12 feet. What was the efficiency of the machine?

(B) A force of 200 pounds was used to lift a resistance of 400 pounds. The force moved 8 feet while the resistance moved 3 feet. What was the efficiency of the machine?

There is always some friction when one body slides over another. It would be impossible to walk if there were no friction; neither could you stop if you were moving. If you have ever walked on an icy surface, you have experienced the difficulty that comes with decreased friction.

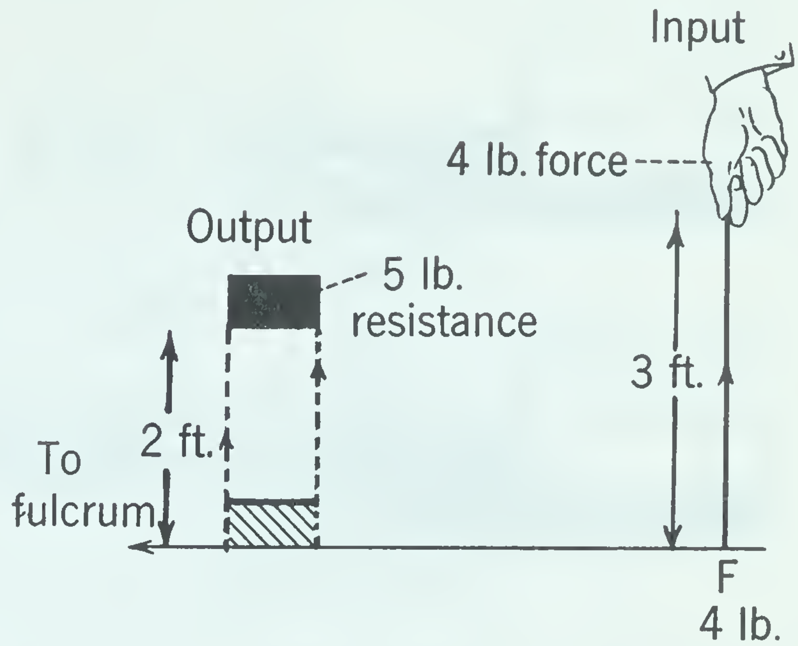


Fig. 13-10. Mechanical efficiency is equal to the output of work divided by the input.

When wheels are used, one surface rolls over another instead of sliding. This type of friction we call ***rolling friction.*** It is easier to pull a heavy ob-

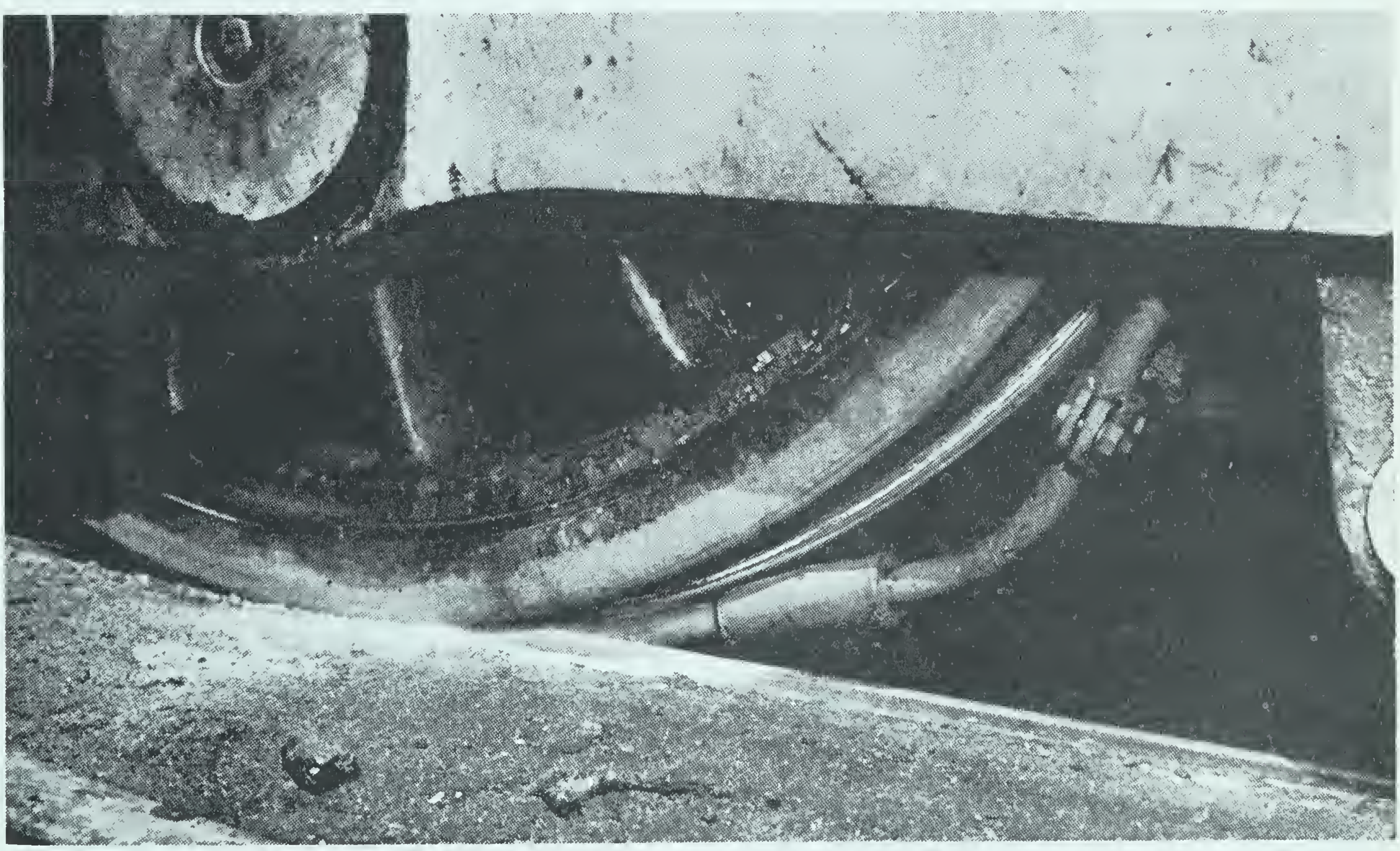


Fig. 13-9. Sand is being poured to increase the friction between the rail and the wheel.

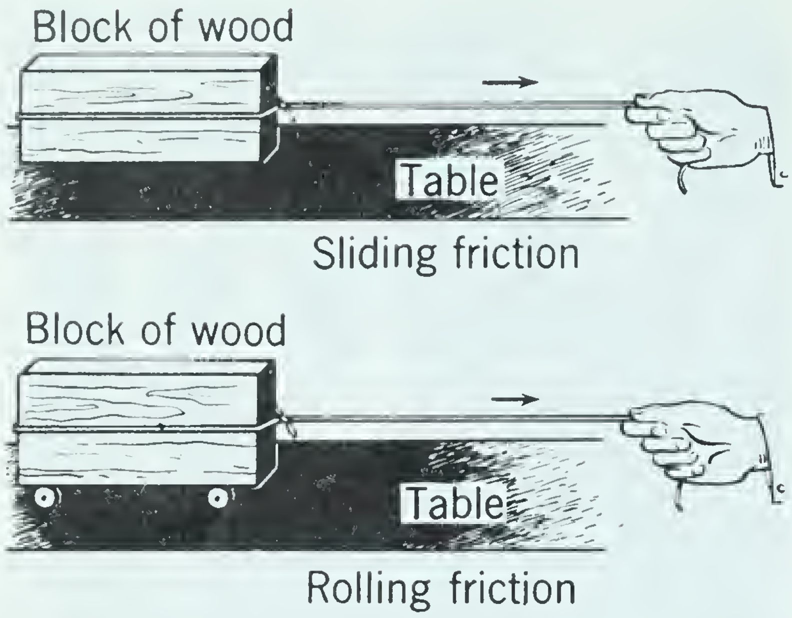


Fig. 13-11. Rolling friction is less than sliding friction.

ject if it is on a wagon than it is to pull it along the ground. ***Fluid friction*** is less than the friction of a solid moved over a solid. It requires less force to move a boat through water than over hard ground. Friction between solids can be reduced by lubrication and by making the surfaces smooth.

PUPIL ACTIVITY

Pull a block of wood along the table with a spring balance. What force is required? Put two small rollers under the block of wood. Metal rods or round pencils may be used. Now repeat the operation. What force is required? Put the block of wood

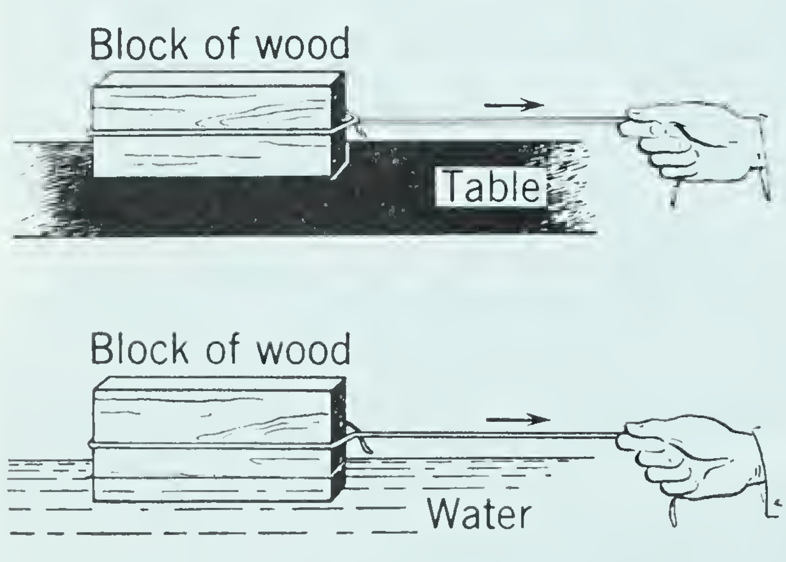


Fig. 13-12. Because of fluid friction, it requires less force to move the box through water than on the table.

in a large pan of water. What force is needed to pull the block of wood through the water? What effect would greasing the block of wood have on the force required to move it along the table?

By decreasing the friction, the efficiency of a machine is increased. We do this by oiling all moving parts, by using ball bearings or soft bearings. Machines will last much longer if kept well oiled.

REVIEW QUESTIONS

1. What is a machine? **2.** For what purposes are machines used? **3.** What is friction? **4.** What is resistance? **5.** What is the output of a machine? The input? **6.** When does the output equal the input? **7.** What is meant when you speak of the efficiency of a machine? **8.** What are the causes of the low efficiency of some machines?

C How are levers used to do work?

A lever is a bar free to turn on some point. If you use a stick to pry up something, it becomes a machine. You can put one end over a log and use the log as the turning point, or *fulcrum* (*full*-krum), as in Fig. 13-13. The object or resistance which you wish to lift is at one end of the stick, and you apply the force at the other end. You can also push one end of the stick under and beyond the object. Then you can lift the object by raising the other end of the stick. In this case the end

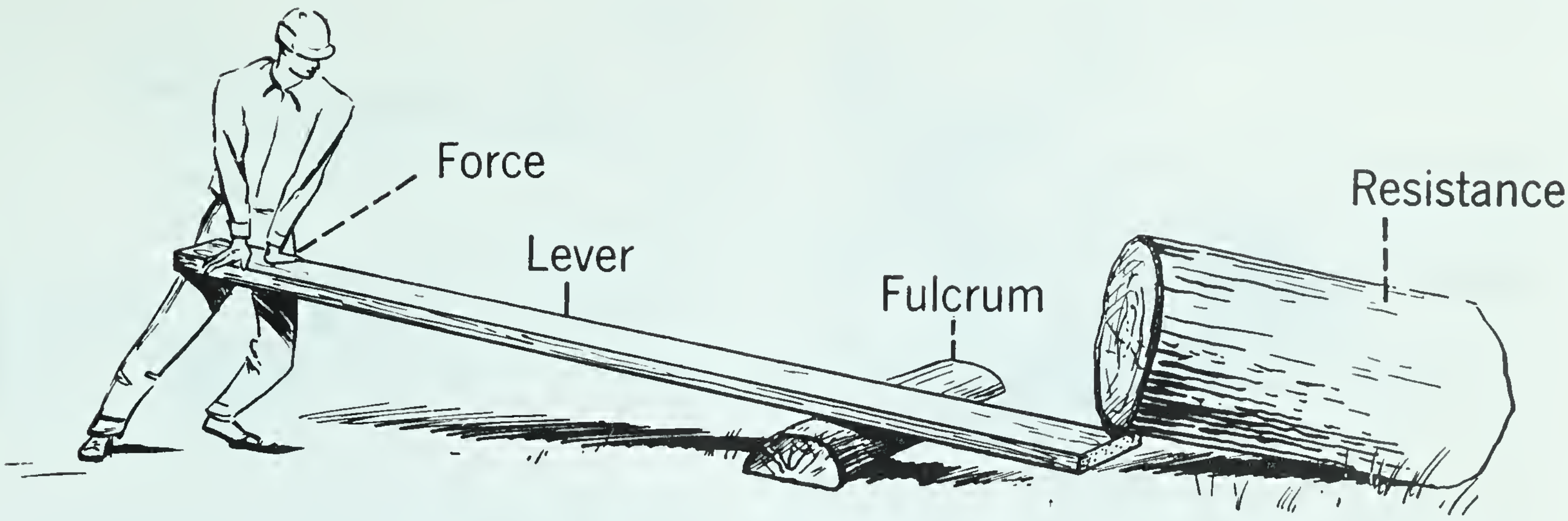


Fig. 13-13. A lever consists of a rigid bar free to turn about a fixed point, the fulcrum.

which rests on the ground becomes the fulcrum.

You can shovel coal by holding the end of the handle of the shovel in one hand and using the other hand to lift the coal. In this case the lifting hand must exert a greater force than the weight of the coal. The *lever* is one of six ***simple machines***. The others are: the *pulley*, the *wheel and axle*, the *inclined plane*, the *screw*, and the *wedge*.

We use levers in three ways and divide them into three classes. The most common type has the fulcrum between the resistance and the force. The force and resistance move in opposite directions. Crowbars, tongs, and scissors are examples of this type of lever. We call levers like these ***first-class levers***.

PUPIL ACTIVITY

Balance a yardstick or meter stick as shown in the diagram in Fig. 13-14. Suspend a weight (resistance) six inches from the balancing point or fulcrum. If weights are not available, apply a resistance by pushing down with your right hand. Use your left hand to apply the force. Suspend a weight one-half the size of the first weight at such a distance from the other side of the fulcrum that the

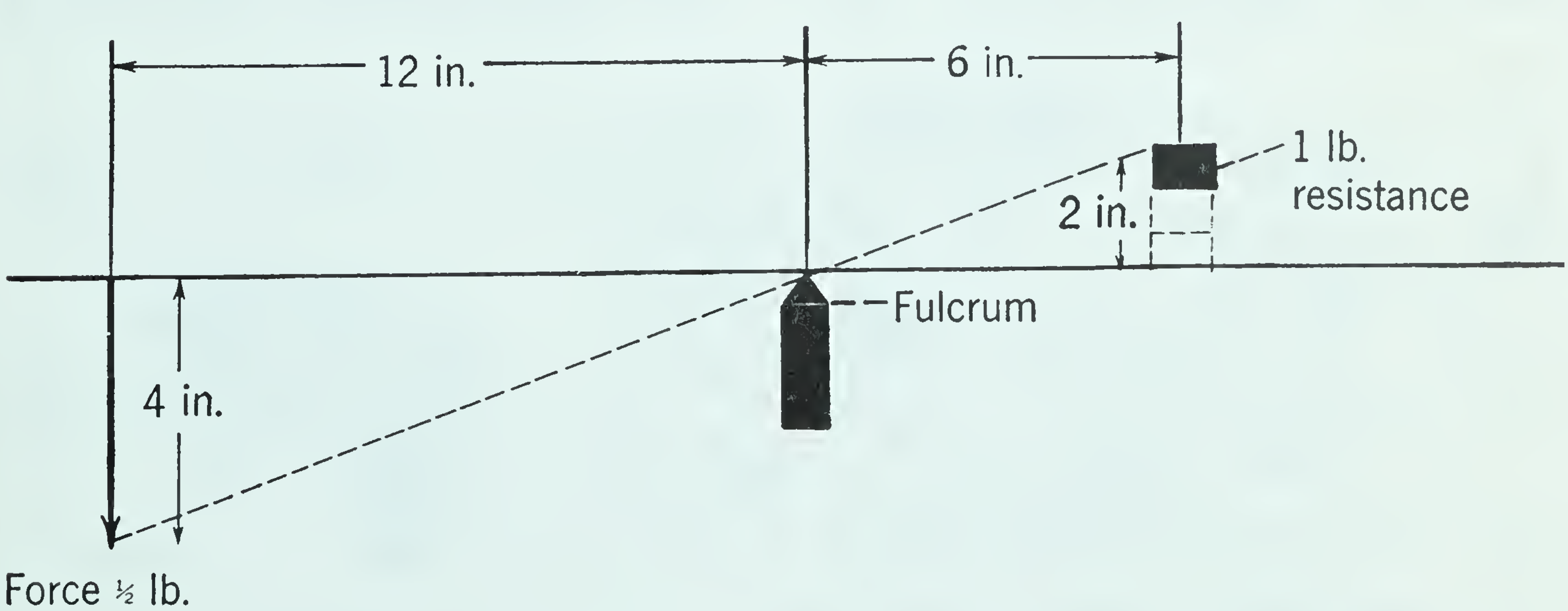


Fig. 13-14. The force exerted times the distance the force moves equals the resistance times the distance it moves.

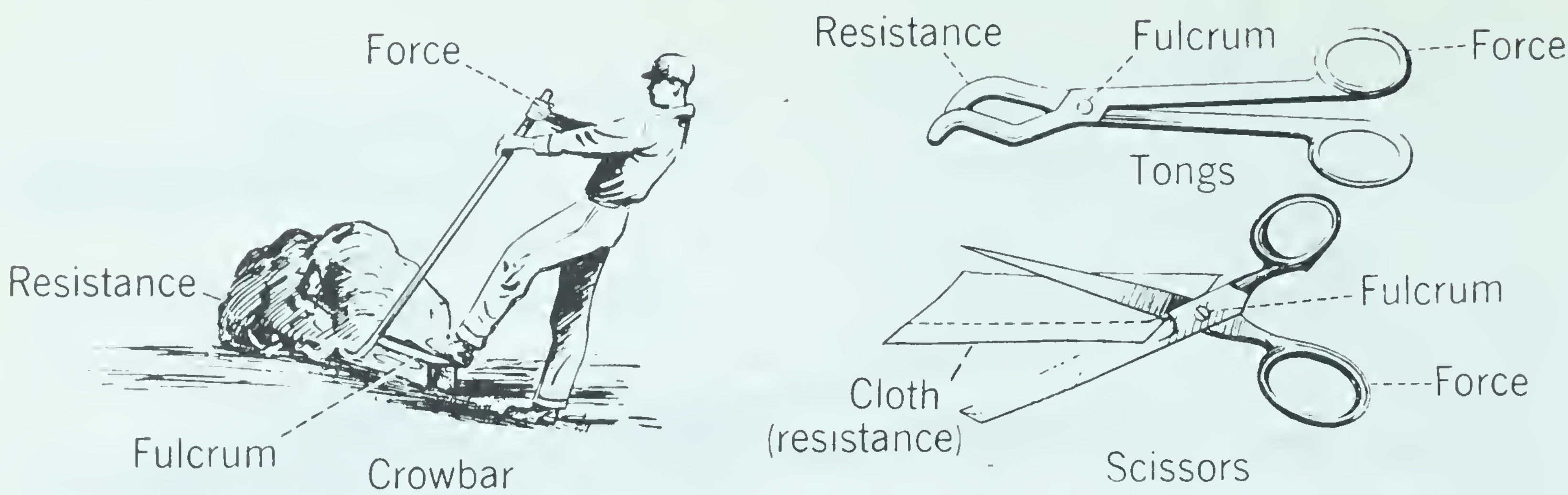


Fig. 13-15. In all first-class levers, the fulcrum is located between the force and the resistance.

stick balances. Move the small weight just enough to cause the balance to tip and raise the larger weight. Bring the balance to a level position. Put rulers directly behind the weights. While the resistance of one pound is moving up two inches, how far does the force move down? Is force or speed gained? If the resistance is greater than the force, force is gained. If the resistance moves more rapidly than the force, speed is gained. Does the force exerted times the distance it moves equal the resistance times the distance it moves?

Put a weight at one end of the stick and move the fulcrum near it. Push down on the other end of the stick. Which is greater, the weight or the force? Which moves more rapidly? What is gained when a lever is used this way?

Next, move the fulcrum away from the weight toward the end where the force is applied. Push down. Is the force greater or less than the weight? Which moves more rapidly? Is speed or force gained?

You can use a first-class lever to gain force, direction, or speed. See Fig. 13-16. What do you gain in using the crowbar, tongs, or scissors which are shown in Fig. 13-15?

The second type of lever has the fulcrum near one end, the resistance being between the fulcrum and force. The resistance and the force move in

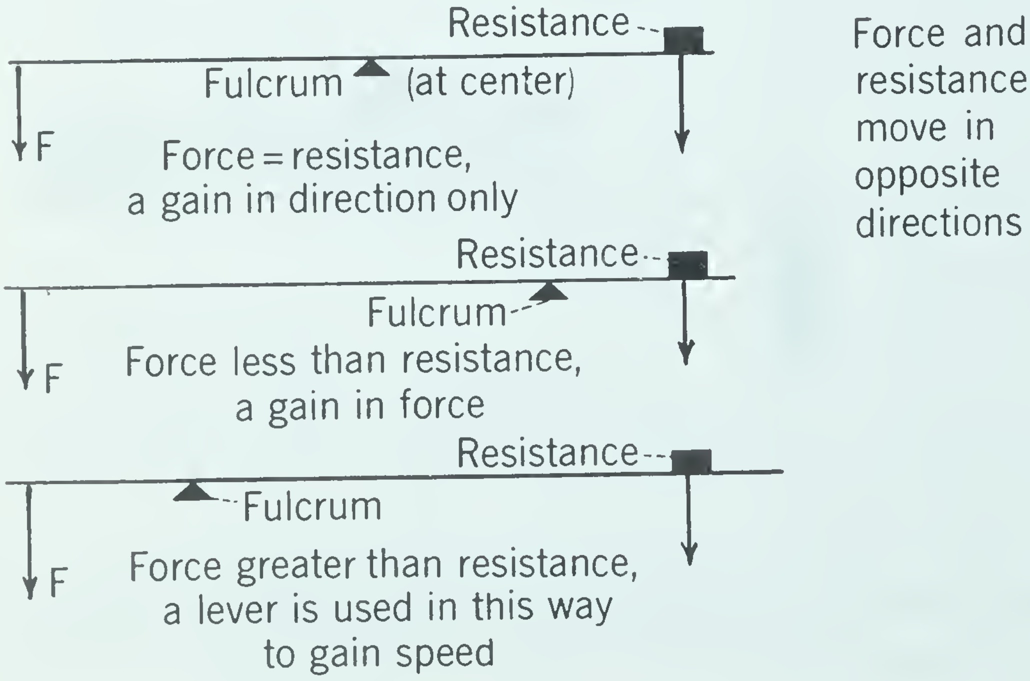


Fig. 13-16. A first-class lever may be used to gain force, direction, or speed.

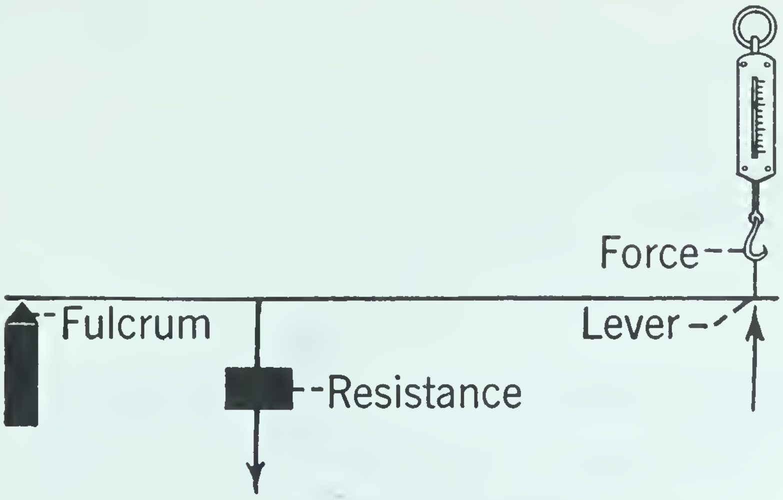


Fig. 13-17. In the second-class lever, the resistance and the force move in the same direction.

the same direction. A lever used in this way is a ***second-class lever.***

PUPIL ACTIVITY

Put the fulcrum near one end of a yardstick or meter stick. Put a spring balance near the other end of the stick. Hang a resistance of known weight between the fulcrum and the balance (see Fig. 13-17). Lift up with the balance. What is the force? Put measuring sticks behind the force and the resistance. How far does the force move up while the resistance is moving up four inches? Which moves faster, the resistance or the force? Is speed or force gained? Repeat by putting the resistance in different positions. Where must the resistance be put if a small force is used?

In using a lever in this way, you usually lift one end of the lever. The wheelbarrow is an example. The fulcrum is at the center of the wheel; you apply the force where your hands grip the handles, and the load is near the wheel. Thus the greater part of the load is on the wheel. This lets you use a small force to hold up the handles. A nutcracker is another example of a second-class lever. In this type of lever, there is always a gain in force. The nearer the resistance is to the fulcrum, the greater is the gain in force.

In the third type of lever the force is between the fulcrum and the resistance. This we call a ***third-class lever,*** and it is used to gain speed. The force and resistance move in the same direction. When you use a spade to lift dirt, the spade is a third-class lever. The dirt to be lifted is the weight or resistance. Your hand holding the end of the handle is the fulcrum, and your hand lifting the spade exerts the force (see Fig. 13-20 on page 379).

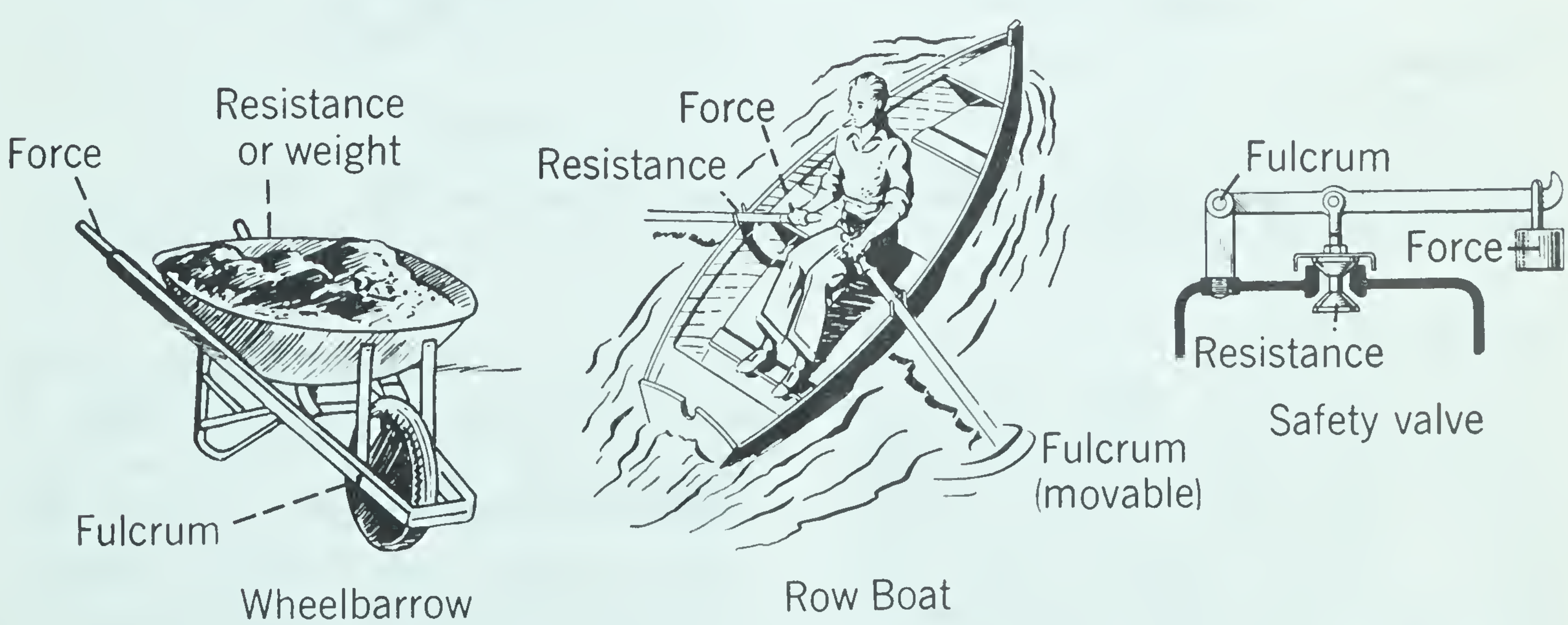


Fig. 13-18. What is gained in the use of each of the levers shown above?

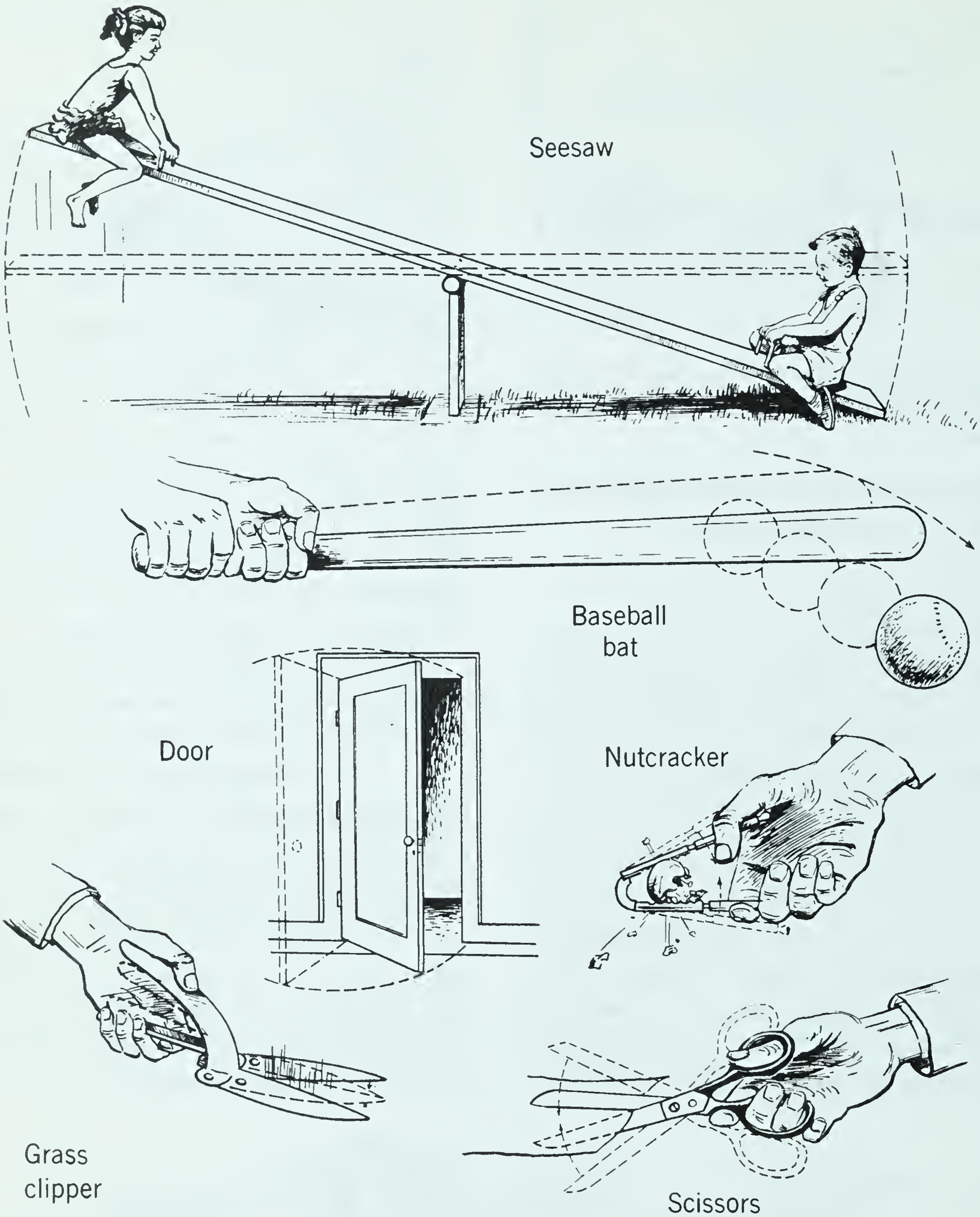


Fig. 13-19. Name the class of lever shown in each of these machines. What is gained in the use of each machine?

DEMONSTRATION

Tie one end of a meter stick or yardstick to some fixed support. Fasten a weight near the other end of the stick. Pull up with the balance placed between the fulcrum and the weight. What force do you need to lift the weight? Is it greater or less than the weight? Which moves more rapidly, the force or the weight? Is speed or force gained by the use of a third-class lever? Repeat, by putting the balance nearer the fulcrum. Results? Now put the balance farther away from the fulcrum. Results?

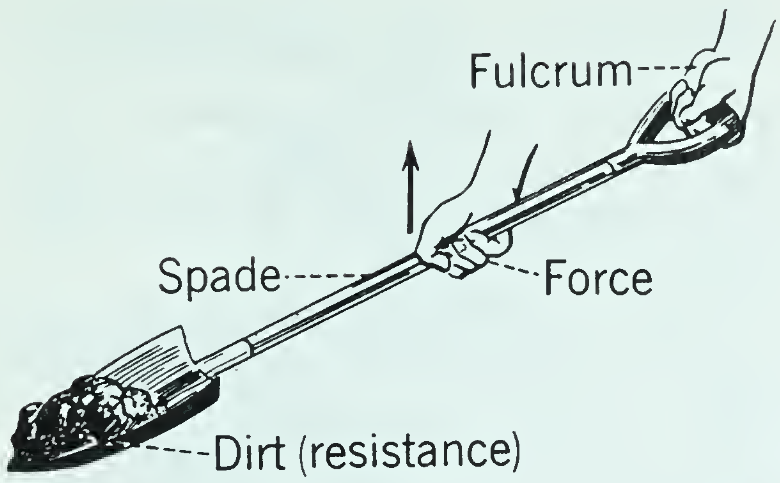


Fig. 13-20. When you lift the dirt with the spade, you are using it as a third-class lever. How can you use it as a first-class lever?

You can use many parts of your body as levers. What class lever do you use in biting something? When you lift some weight in your extended hand? In each case, explain where you exerted the force, where the fulcrum is, and where the resistance is. Compare the resistance you overcome with the force you use.

REVIEW QUESTIONS

1. What is a lever? **2.** How are the fulcrum, force, and resistance arranged in the three different classes of levers? **3.** How can levers be used to gain speed? To gain force? To change direction? **4.** Explain by means of diagrams how a first-class lever 6 feet long can be used to lift a resistance of 100 pounds with a force of 25 pounds; to lift a resistance of 50 pounds with a force of 150 pounds (the fulcrum is at the center of the lever).

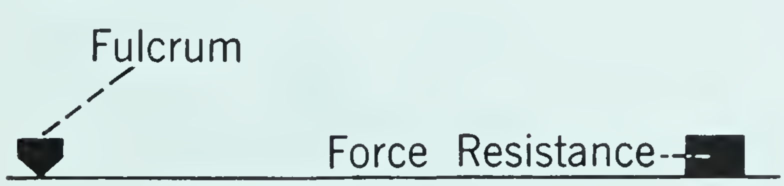


Fig. 13-21. Speed is gained in a lever when the force is exerted between the resistance and the fulcrum.

5. Make a diagram of a second-class lever to show how a resistance can be made to move 6 inches while the force moves 15 inches. **6.** Make a diagram of a third-class lever to show how a resistance can be made to move 20 inches which the force moves 5 inches.

D How are the pulley and the wheel and axle used to do work?

A pulley is a modified form of the lever. Did you ever think of a pulley as a machine? We apply force at one side and the resistance is at the other side. The wheel of a fixed pulley is free to turn but not to move up or down. Think of a pulley as a first-class lever which acts continuously. The fulcrum is at the center of the wheel.

You attach a single *fixed pulley* to a fairly high support. Then, you use it to raise a resistance through a distance which would be impossible by using an ordinary lever.

A movable pulley has one end of the rope attached to some support. Then you attach the pulley to the resistance. It moves with the resistance. In this case, the weight is supported by two ropes. The weight moves through half the distance covered by the free end of the rope. The effect is like a second-class lever with the resistance half-way between the fulcrum and the effort force. This gives a gain in force.

We use pulleys to gain force, to change direction, or to gain speed.

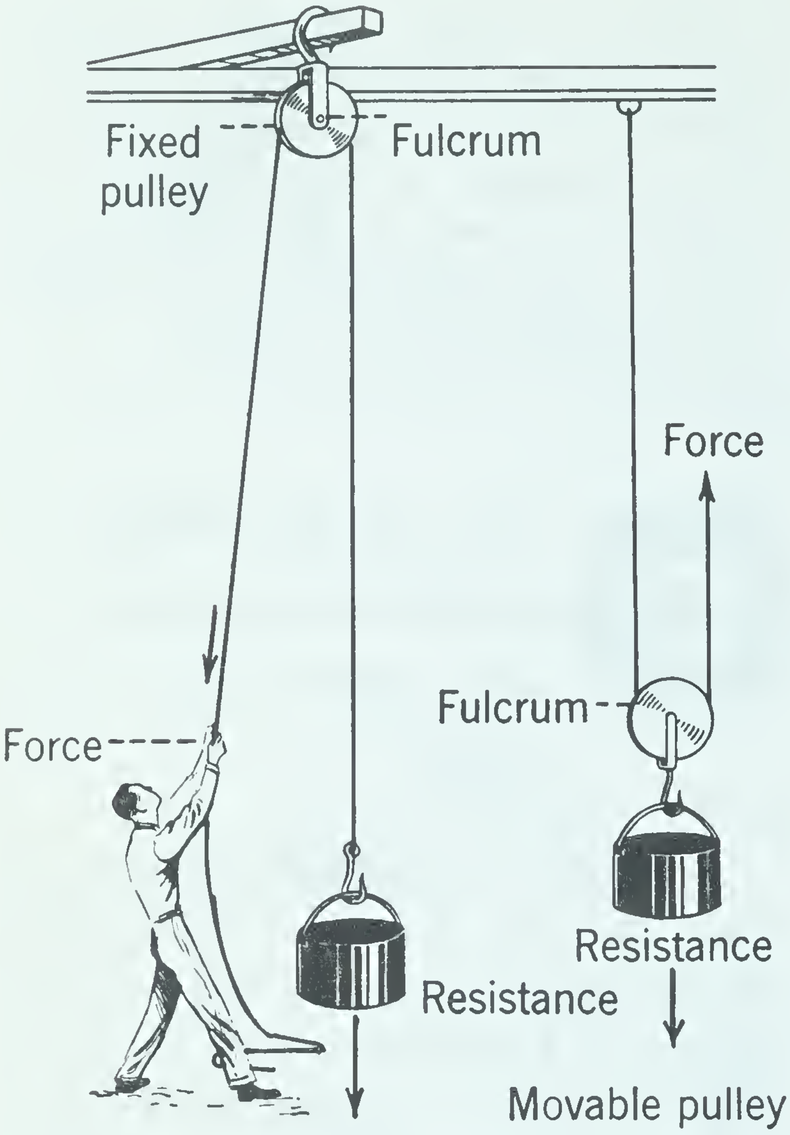


Fig. 13-22. What two uses of pulleys does this diagram illustrate?

PUPIL ACTIVITY

Tie one end of a string to a one- or two-pound resistance. Hook a pulley to one of the rings on a ring stand. Put the loose end of the string over the pulley. How much weight must be added to the end of the string to balance the resistance of two pounds? While the resistance is moving up one foot, how far does the force move down? Locate the fulcrum, weight, and force.

Repeat the demonstration by using the pulley as a movable pulley (Fig. 13-23). What force do you need to lift the resistance? How far does the force move up while the resistance is moving up one foot?

Set up a pulley as shown in the third case in Fig. 13-23. Hook the spring balance to the pulley. Pull up on the balance. What force is needed to lift the resistance? How far does the resistance move up while the spring balance moves up one foot? Is force or speed gained by using the pulley in this way? If the resistance is ten pounds in the above case, how much force must be exerted in order to balance it?

In using a fixed pulley, you pull down to raise a weight. You gain neither force nor speed. But you can raise a weight to any height if you have the necessary support for the pulley.

Some windows use fixed pulleys.

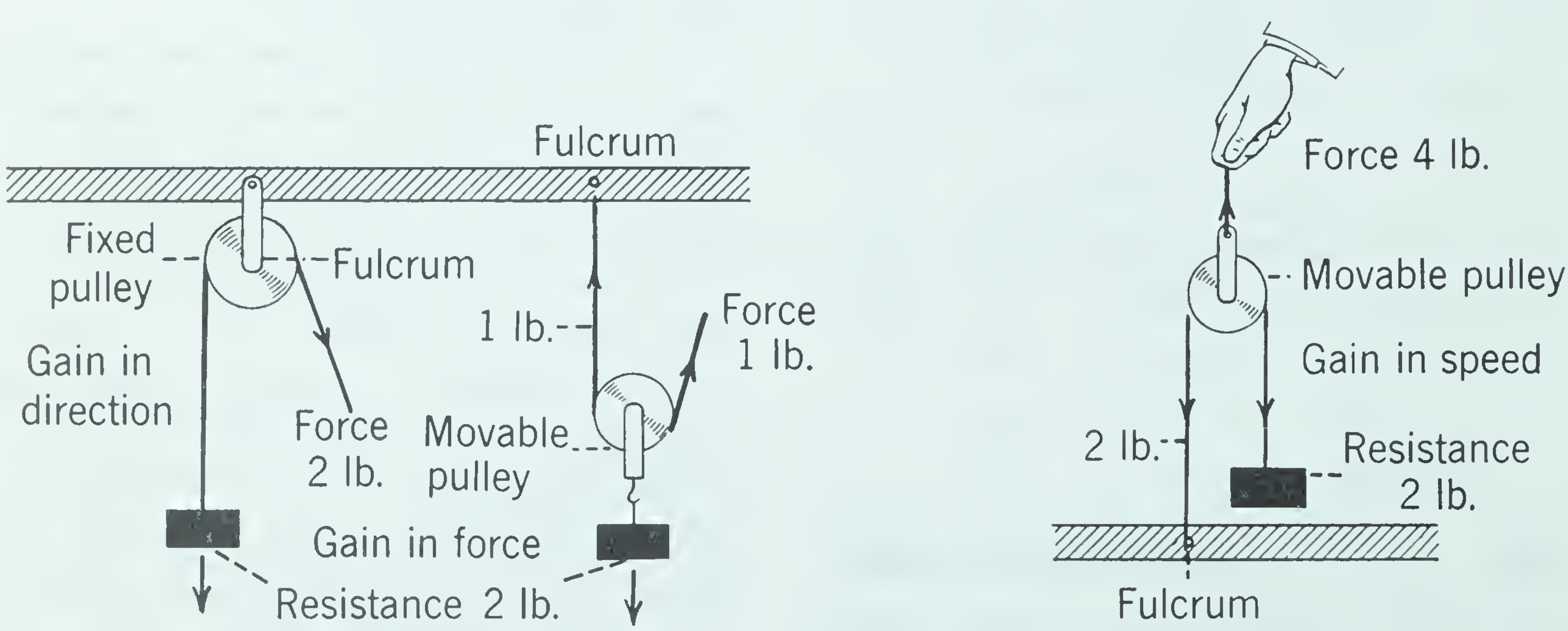


Fig. 13-23. A single fixed pulley can be used to change direction. A single movable pulley can be used either to gain force or speed.

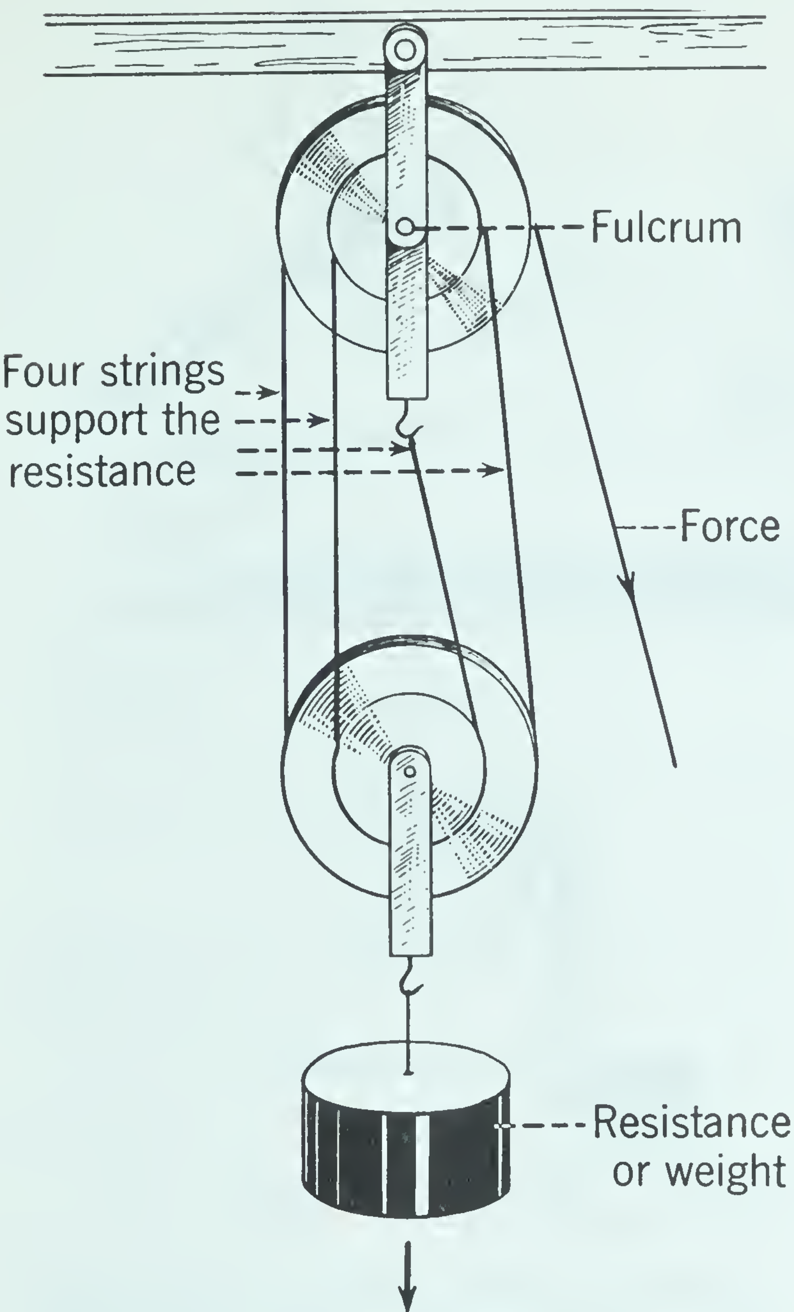


Fig. 13-24. To lift heavy objects, a combination of fixed and movable pulleys may be used.

One end of the rope is attached to the window and the other end to a weight which moves up and down between the walls. The weights are about equal to the weight of the window so that you can raise or lower the window with a small force.

A system of fixed and movable pulleys is used to lift heavy resistances. Heavy objects, such as pianos and safes, frequently are raised by using a combination of fixed and movable pulleys, as shown in Fig. 13-24. With this system of pulleys a force of 125 pounds could be used to lift a 500 pound weight, disregarding friction.

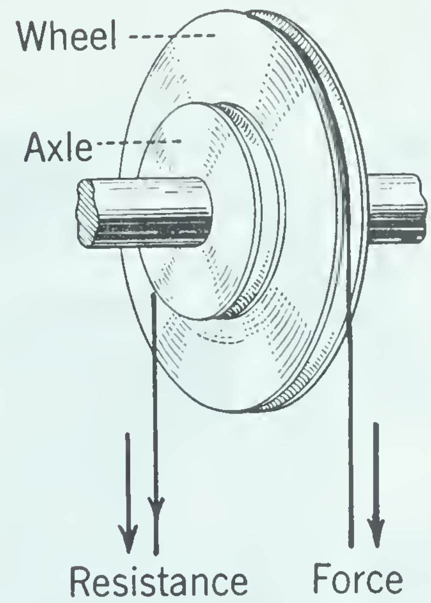


Fig. 13-25. How can you gain force and speed by using the wheel and axle?

A wheel and axle has wheels of two different diameters fastened together. A wheel and axle acts like a rotating lever. It may have two wheels of different diameters attached to each other; a large wheel attached to a smaller axle; or a handle attached to an axle. How does the handle represent the larger wheel? Common examples of the wheel and axle are the windlass, steering wheel, egg beater, bicycle pedals, door knob, clothes wringer, and screwdriver.

The wheel and axle can be used to gain force or speed. To gain force, we must apply the force to the outer edge of the large wheel. The resistance is applied to that of the axle. To gain speed, we use just the opposite arrangement. What we gain in force, we lose in speed.

REVIEW QUESTIONS

1. What is a fixed pulley? **2.** What is a movable pulley? **3.** What advantage is gained in using a fixed pulley? **4.** What kind of pulley is used to raise and lower a window? To raise a flag to the top of a

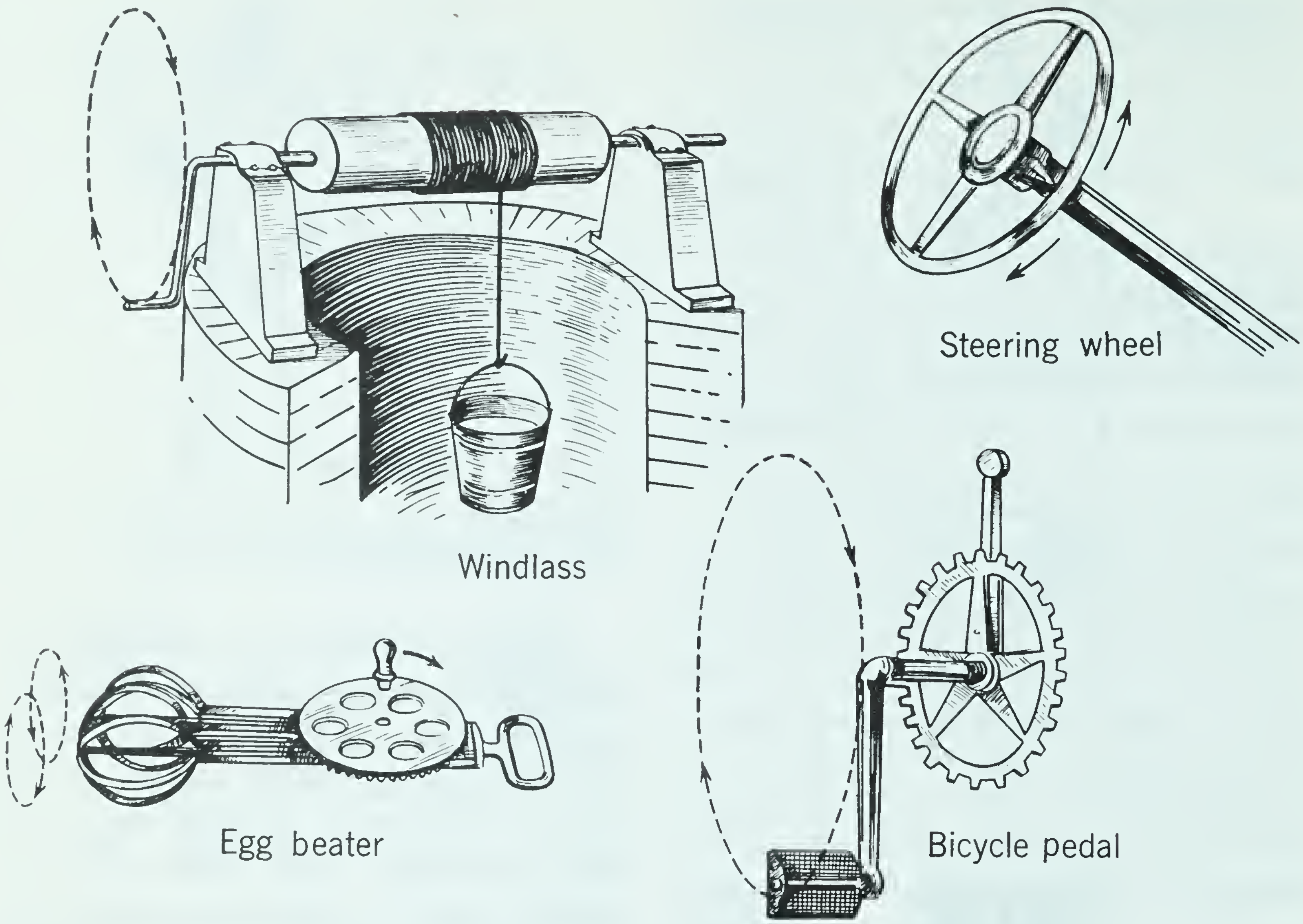


Fig. 13-26. All these machines are examples of the wheel and axle.

flagpole? **5.** What system of pulleys is used to lift heavy objects? **6.** How can a wheel and axle be used to gain force? How can it be used to gain speed? **7.** Is force or speed gained in using two fixed and two movable pulleys?

E How are inclined planes used to do work?

Inclined planes can be straight or curved. If you roll a barrel up a plank to a platform or pull a wagon up a hill, you are using an *inclined plane.* If you use a knife to cut bread, you are using a double inclined plane or *wedge.* Spiral inclined planes are called *screws.* If you follow the threads of a screw with a pencil point, you will notice that you are going around it in a spiral inclined plane.

DEMONSTRATION

Pull a loaded toy car up an inclined plane by a spring balance (see Fig. 13-27). Read the balance while you are pulling the car. Weigh the load and car. Measure the length and height of the plane.

What force is necessary to pull the car (resistance) up the plane? How far did the force travel? How heavy is the resistance? How far is the load lifted by using the plane? Does force times distance equal resistance times distance? What is gained in using the plane? If a plane is 12 feet long and raised 3 feet at its higher end, what force is needed to roll a barrel

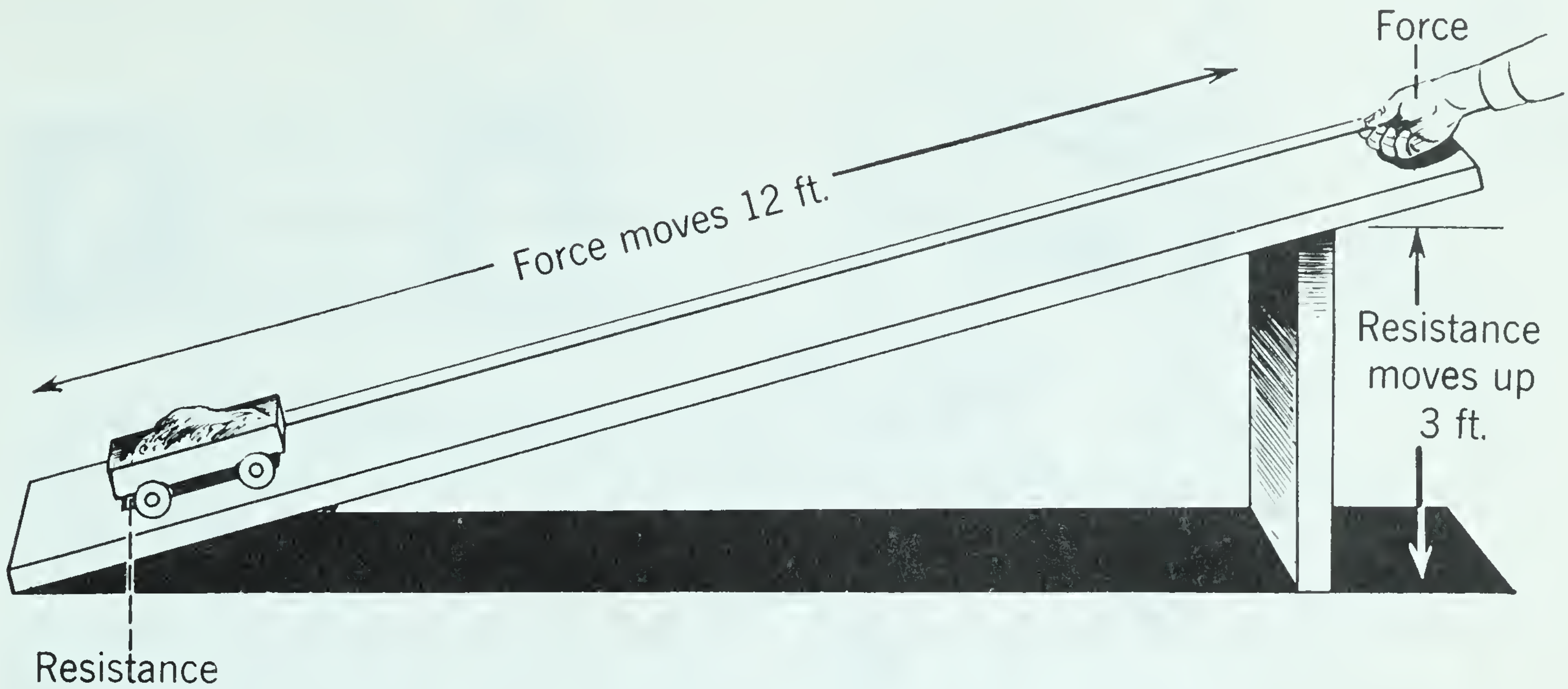


Fig. 13-27. When you wish to raise an object without exerting the force to lift it vertically, you can use an inclined plane.

weighing 200 pounds up the plane? (Disregarding the friction.)

In this problem the force of 50 pounds moving through a distance of 12 feet can move a weight of 200 pounds through a vertical distance of 3 feet if there is no friction. The force needed is only one-fourth as much as the weight. But the distance through which the force acts is four times as great as the distance through which the weight is lifted. An inclined plane makes it possible to raise a resistance by using a force smaller than the resistance. The distance the force moves is the length of the plane. The distance

Fig. 13-28. The escalator is an application of the inclined plane.

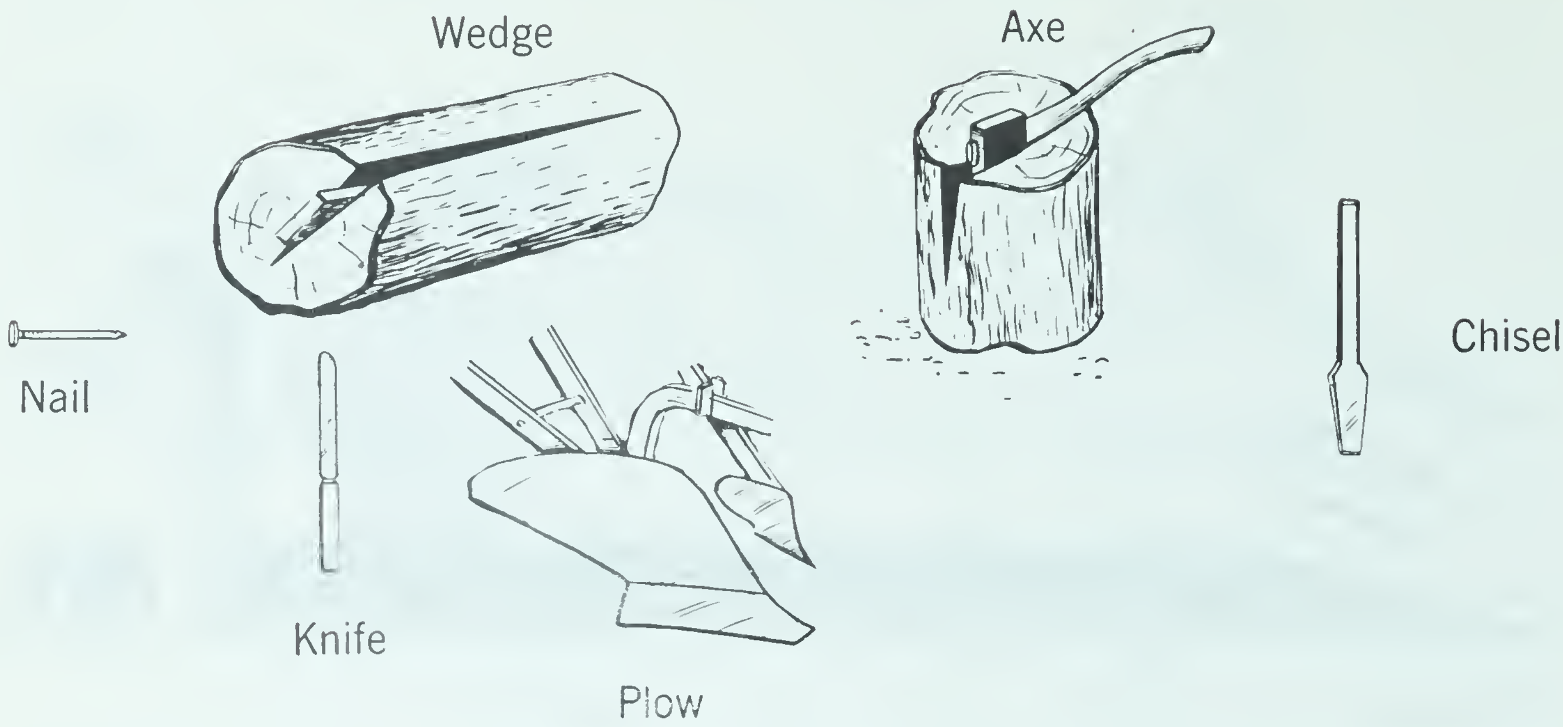


Fig. 13-29. All these are forms of the wedge which is a double inclined plane.

the resistance is lifted is the height of the plane.

The wedge is a double inclined plane. The blade of a knife, the teeth of a saw, the chisel, and the axe are forms of the wedge. The force applied to a wedge is used to drive it under or against the resistance.

The screw is a spiral inclined plane. The screw makes it possible to overcome a large resistance with a small force. Due to its friction, its efficiency is low. Friction in many cases makes it advisable to use the screw. Two boards, for example, are held together by the friction between the wood and the screw. When you use a jack to raise a car, it will hold the car at any height because of its friction. If its friction were low, the weight of the car would make it unwind and return to its lowest level.

The propellers on boats and airplanes are forms of the screw. The propeller goes forward as it turns, taking the boat or plane with it, as a screw pulls forward when it turns in wood. The blades of an electric fan act like a screw in pushing air forward.

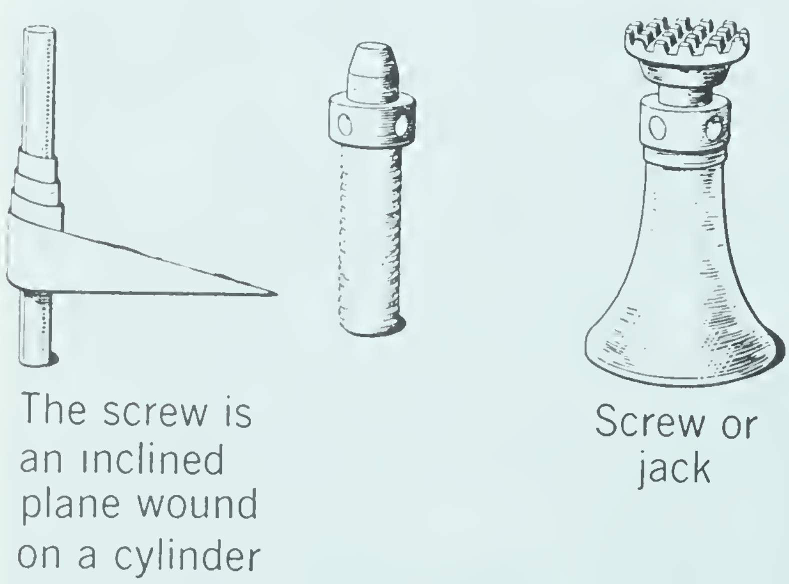


Fig. 13-30. The screw is a circular inclined plane.

REVIEW QUESTIONS

1. Under what conditions are inclined planes, wedges, and screws used? **2.** Show by a drawing the length and height of an inclined plane. Also indicate the distances the resistance and force move. **3.** In what ways is friction helpful in the operation of these machines? **4.** In what ways is friction a hindrance?

F How are forces transferred from one machine to another?

In factory buildings of the past it was often necessary to run several machines from the main driving shaft. These machines usually ran at different speeds and sometimes even in different directions. Some were in a line parallel to the main shaft while others were at angles with it. Belts, gears, and chains made it possible to run all these machines from one source of power.

Nowadays modern factories usually run each individual machine by an electric motor. You can see that this system is much more efficient than the older one.

Belts transfer a force from one wheel to another to gain force or speed or change the direction in which the force acts. Probably you have used a string to run a machine with a small electric motor. The string acted as a belt.

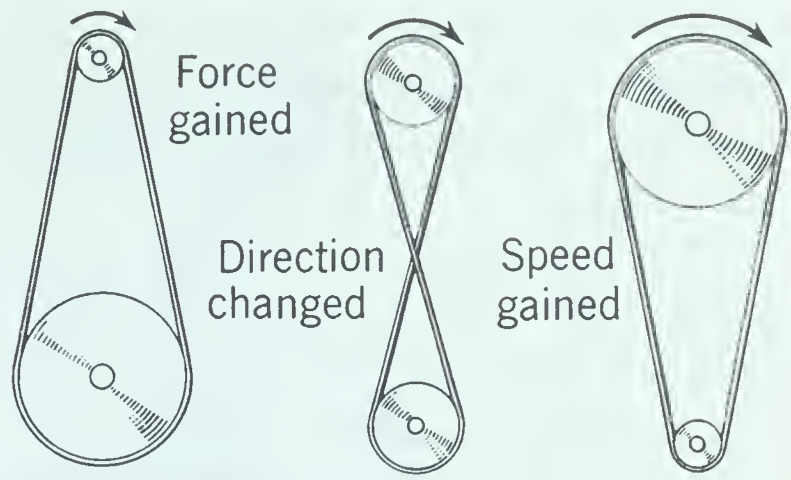


Fig. 13-31. How can you change the direction of the driven wheel?

Belts are also used in sewing machines, washing machines, automobiles, and many other machines.

Compare the speed of the driven wheel with that of the driving wheel in each diagram in Fig. 13-31. The direction in which the driving wheels turn is indicated by the arrows.

The driven wheel can be made to turn faster or slower by using a larger or a smaller driving wheel. You can change the direction of the driven wheel by crossing the belt. Some force is lost in driving a machine with a belt.

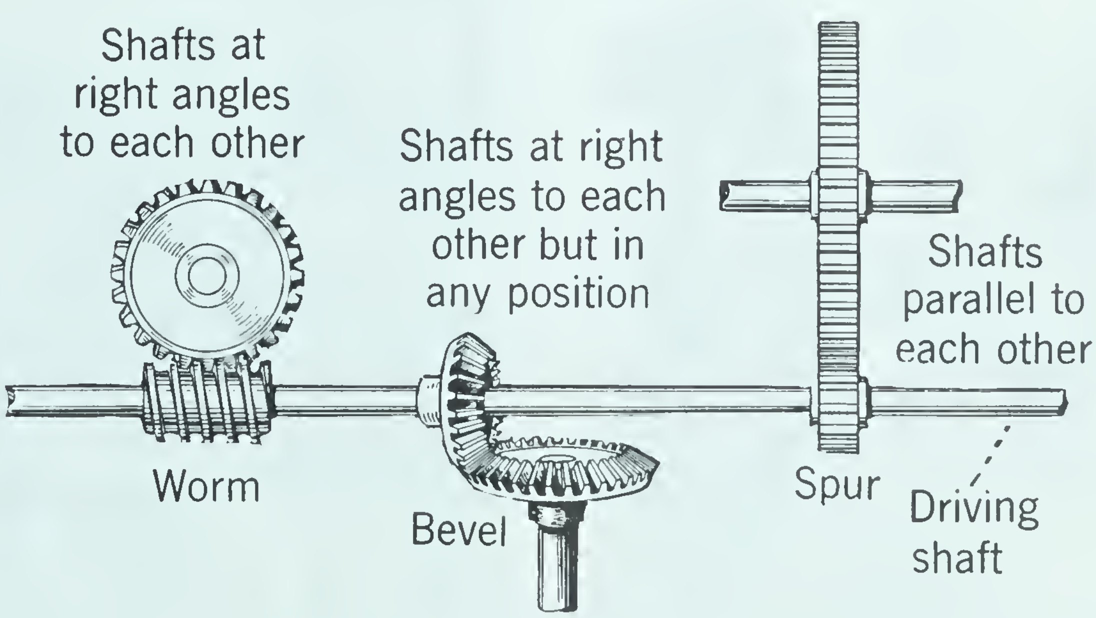


Fig. 13-32. Gears, a modified form of the wheel and axle, can be used to gain speed, force, or direction.

It not only requires force to bend the belt as it goes around the wheels, but also the belt may slip if the load is very heavy.

The two wheels are a form of the wheel and axle or of the separate levers. A force applied to a small wheel can overcome a greater resistance on a large wheel. But the larger wheel makes fewer rotations. What is gained in force is lost in speed.

Gears can be used to gain speed, force, or direction. The gear wheels are so arranged that the cogs or teeth on one wheel fit the cogs on another.

Gears can be so arranged as to drive another wheel in the same straight line, or at various angles. They are all modified forms of the wheel and axle.

The three main types of gears are shown in Fig. 13-32. What different machines can you think of which use these?

Chains are used to transfer force from one place to another. You know your bicycle is driven by a chain. The sprocket on the rear wheel is connected by a chain to the sprocket wheel to which the pedals are attached. The chain has special links which fit over the teeth on the two sprocket wheels. The front sprocket wheel is used to gain force. The force is applied to the pedals. The rear sprocket and bicycle wheel are used to gain speed because the rim of the rear wheel moves faster than the pedals.

Chains are stronger than belts and cannot slip. They are fine for bicycles and heavy machinery, but are clumsy for other uses. Also, their parts get broken which makes them unsuitable for many purposes.

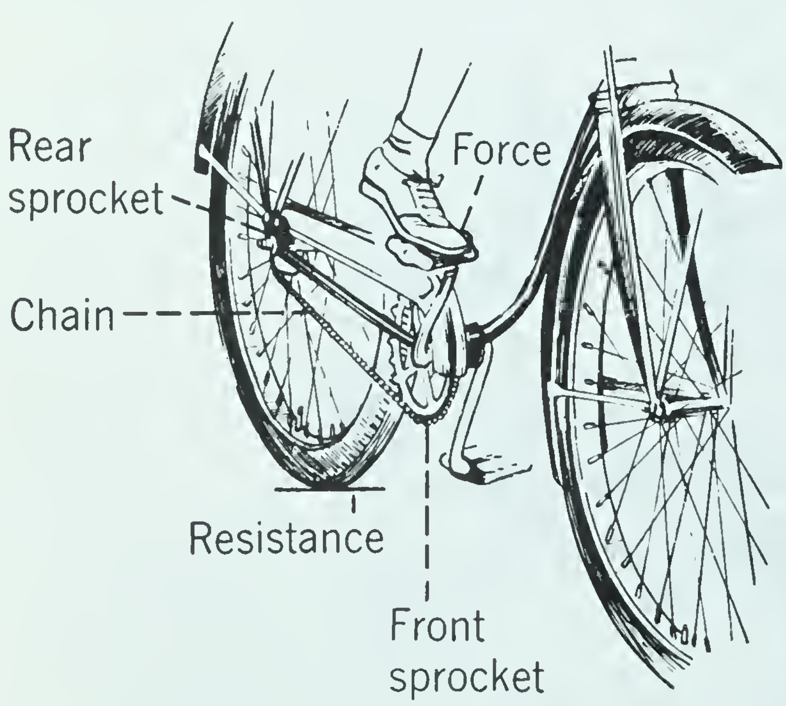


Fig. 13-33. How does the chain on this bicycle work like a belt?

REVIEW QUESTIONS

1. In what three ways can force be transferred from one wheel to another wheel? **2.** Explain how speed can be gained by the use of belts. **3.** How is direction changed by the use of belts? **4.** What are three kinds of gears? **5.** Under what conditions are chains used?

G What compound machines are in common use?

A compound machine is a combination of two or more simple machines. Many jobs cannot be done with one simple machine, so we often combine several of them. The result is a *compound machine.* In such machines, the total work done is the same as the work accomplished by each of the simple machines working alone.

We often use compound machines to overcome large resistances with small forces. Look around your house and see how many compound machines there are! Many of these tools and utensils are made of simple machines grouped so as to do the desired work. Let us examine the vise, meat chopper, can opener, and water faucet —just as a few typical examples (Fig. 13-35). What other examples can you name and identify?

The vise has two jaws to hold an object firmly in position. You apply a small force to the end of the handle. What happens then? This small force will overcome a resistance of many pounds.

You use a screw to fasten the vise to a bench. You use another screw to move the jaws back and forth. The long handle is a lever which turns the screw. The jaws are held together by a force applied to them as levers.

Fig. 13-34. The bicycle is a compound machine. Identify the simple machines used.

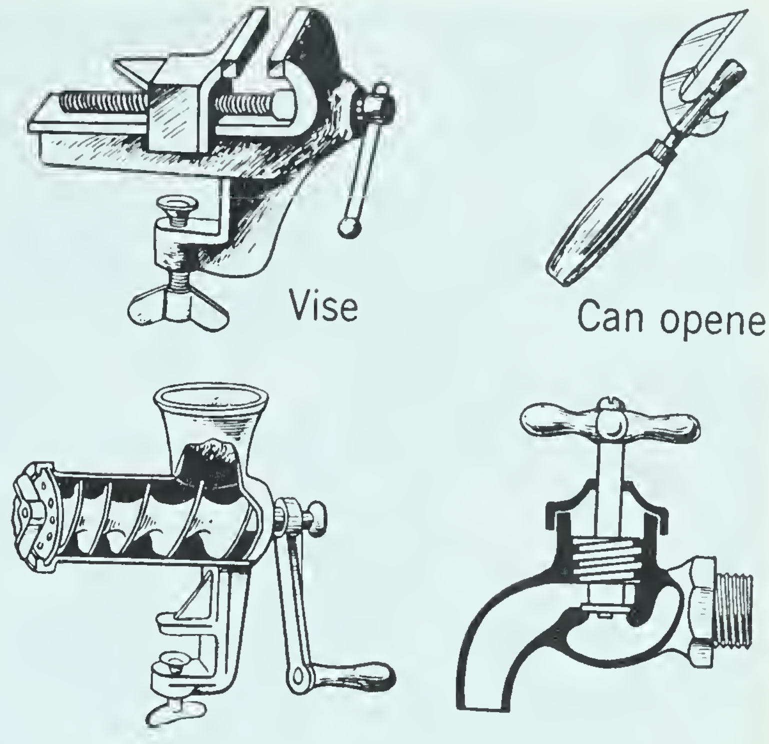


Fig. 13-35. What simple machines are used in these compound machines?

The meat chopper has a clamp, a screw, a long handle, and cutting edges. You use the clamp to fasten the chopper to the table. The screw then moves the meat forward to be cut, and the handle overcomes a large resistance with a small force. The cutting edges are forms of the inclined plane.

The faucet contains a screw which is attached to the water pipes. A screw is also used to hold the valve in position. The handle acts as a lever in opening and closing the faucet. The washer acts like a wedge. By applying a small force with your fingers, you can overcome water pressure of more than 80 pounds per square inch.

Many can openers use a wedge or inclined plane as the cutting edge and a handle as a lever. In the can opener in Fig. 13-35, the wedge on the end is used to punch a hole in the can. The handle acts as a lever to increase the force of the cutting edge against the lid of the can.

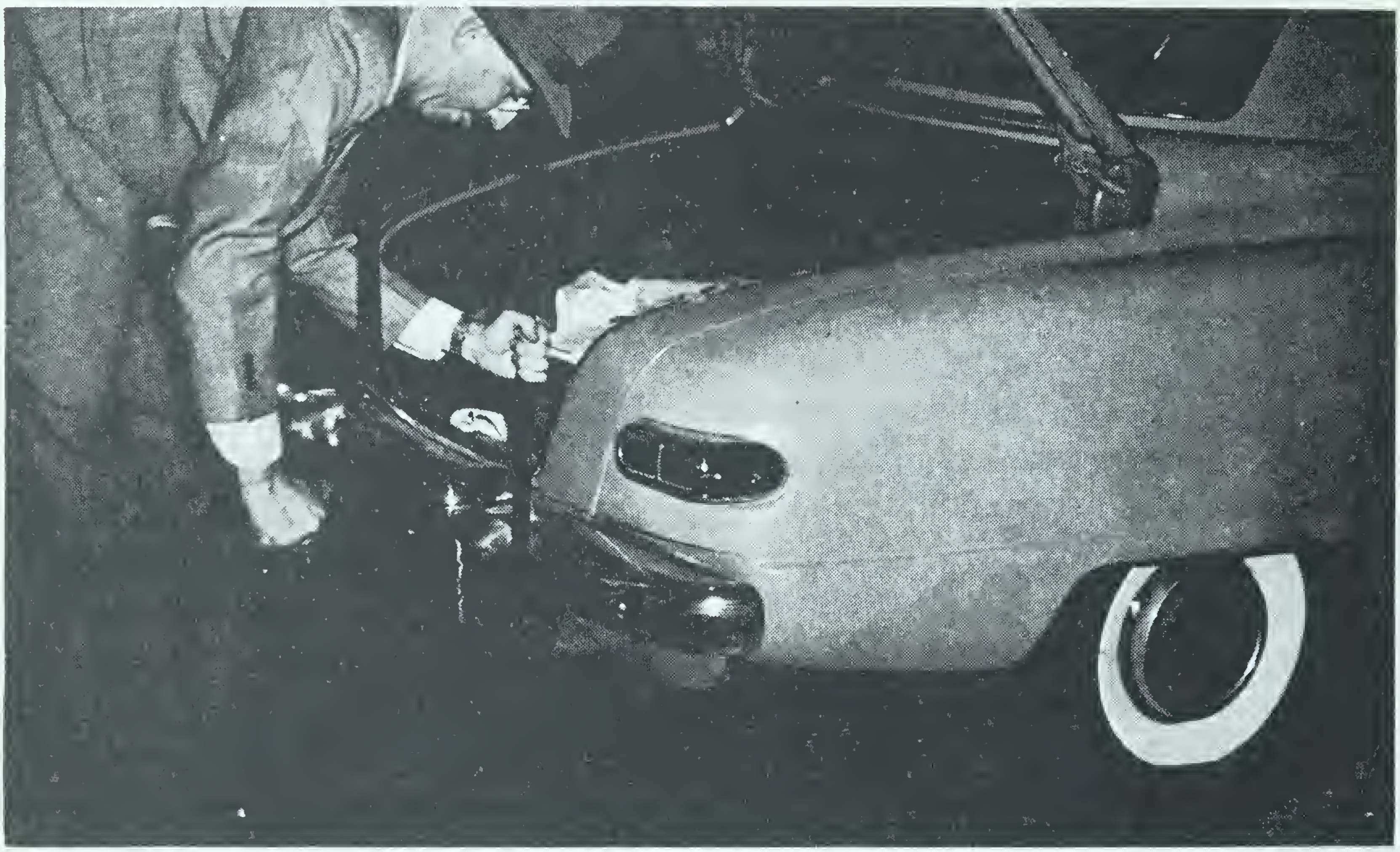


Fig. 13-36. The automobile jack is an example of a compound machine.

The automobile jack is also a compound machine. You may be surprised to know you can lift one-fourth to one-half the weight of a 4,000-pound car with this machine. All you do is apply a small force at the end of the handle—but your hand must move through a much greater distance than the car is lifted. Here again, you gain force at the expense of speed.

We cannot describe all the compound machines used in and around our homes. But they make possible many different kinds of work. Other compound machines are: carpet sweeper, insect spray gun, hand ice cream freezer, egg beater, light switch, pipe wrench, pliers, lock, and plane.

Most of our many electrical appliances are also examples of compound machines. The force is supplied by an electric motor.

REVIEW QUESTIONS

1. What is a compound machine? Give three examples. **2.** Of what simple machines are (a) the vise; (b) meat chopper; (c) faucet; and (d) can opener composed? **3.** How do they operate?

QUESTIONS FOR REVIEW AND DISCUSSION

1. What was probably the first form of simple machine to be used?

2. Why was the invention of the wheel important?

3. Who is credited with introducing the science of mechanics?
4. What is the definition of work? In what units is work measured?
5. What is a force? How is a force measured?
6. What is energy? What are the two kinds of energy? Give two examples of each.
7. What is power? In what units is power measured?
8. What is a machine? What are the six types of simple machines?
9. What are the three classes of levers? What is the position of the fulcrum, force, and resistance in each class?
10. How is the principle of work applied in each class of lever?
11. What class or classes of levers is used to: (a) change direction; (b) obtain a gain in force; (c) obtain a gain in speed?
12. Distinguish between fixed and movable pulleys. Under what conditions is each kind of pulley used?
13. How can a pulley be used to gain force?
14. What is a wheel and axle? Under what conditions is a wheel and axle used?
15. Explain why a wheel and axle is a modified form of lever.
16. Explain how the principle of work is applied in the wedge, screw, and inclined plane. What is gained with the use of each? Under what conditions is each machine used?
17. In using a wheelbarrow:
    (a) Where is the resistance?
    (b) Where do you apply the force?
    (c) In what directions do the force and resistance move?
    (d) What distance does the force move compared with the resistance?
    (e) What is gained in the operation of this machine? What is lost?
18. In rowing a boat:
    (a) Where is the fulcrum?
    (b) What is the resistance?
    (c) Where is force applied by the person rowing?
    (d) Where is force applied to the resistance?
    (e) What class lever is used?
    (f) In what direction does the force move? In what direction does the resistance move?
    (g) Is the force larger or smaller than the resistance?
    (h) What is gained in the operation of this machine?
19. What methods are used to decrease friction?
20. In what ways can force be transferred from one wheel to another wheel? Why is this done?
21. What is a compound machine? What compound machines are used in your home?
22. What is friction? In what ways does friction hinder us in the use of machines? In what ways does friction help us?

23. Make a chart for the following simple and compound machines, telling what machine or machines is used in each, and for what purpose each is used: (a) tack puller, (b) fork, (c) shears, (d) nutcracker, (e) tongs, (f) bicycle, (g) wheelbarrow, (h) typewriter, (i) sewing machine, (j) meat grinder, (k) egg beater, (l) vise, (m) can opener, (n) knife, (o) hammer, (p) wrench, (q) automobile jack, (r) screw driver, (s) saw, (t) test tube holder, (u) forceps, (v) axe.

SPECIAL REPORTS AND PROBLEMS

1. Construct a model of some machine with "Erector" or "Meccano" sets.
2. Demonstrate how some compound machine is constructed and operated.
3. Report on McCormick's reaper.
4. Report on Howe's sewing machine.
5. Set up and measure the efficiency of some commonly used simple machine.
6. Report on the history of the plow.
7. Report on the history of early tools and machines.
8. Demonstrate some of the simple and compound machines used in the home.

TESTING THE PURPOSES OF THIS UNIT

1. Define or explain the meaning of each of the following words or terms: energy, work, power, force, machine, lever, pulley, wheel and axle, inclined plane, wedge, screw, friction, compound machine, foot pound, fulcrum, resistance, horsepower, input of machines, output of machines.
2. Why is it impossible to get more work out of a machine than is put into it?
3. What do we mean when we say that machines save labor? Do they decrease the amount of work to be done?
4. What effect has the invention of machines had on the amount of work a man can do in a day? On the length of the working day?
5. How long have simple machines been in use? Has a new simple machine been discovered in the last two thousand years?
6. Why are more machines used now than ever before?
7. What different forces or forms of energy are used to run machinery now?
8. In what ways will a knowledge of machines be of help to a mechanic? To an engineer? To a farmer? To a housewife?
9. In your opinion should the use of machinery be discouraged in order to give men work? On what do you base your opinion?
10. In what ways are you dependent on the use of machines?
11. Why does a good mechanic or engineer need to be an efficient user of tools?

The old

SIMPLE MACHINES, ESPECIALLY THE LEVER AND THE INclined plane, have been used from the earliest times. Man found out that by their aid he could move heavy objects, split tough logs, and do many other things that he could not do with his bare hands. The simple machines were not often combined in complicated ways until the invention of the steam engine.

Also, the use of great water power gave man a source of larger quantities of energy than the muscles of men and animals could produce. With this greater supply of force available, men began to construct larger and more intricate compound machines for different purposes.

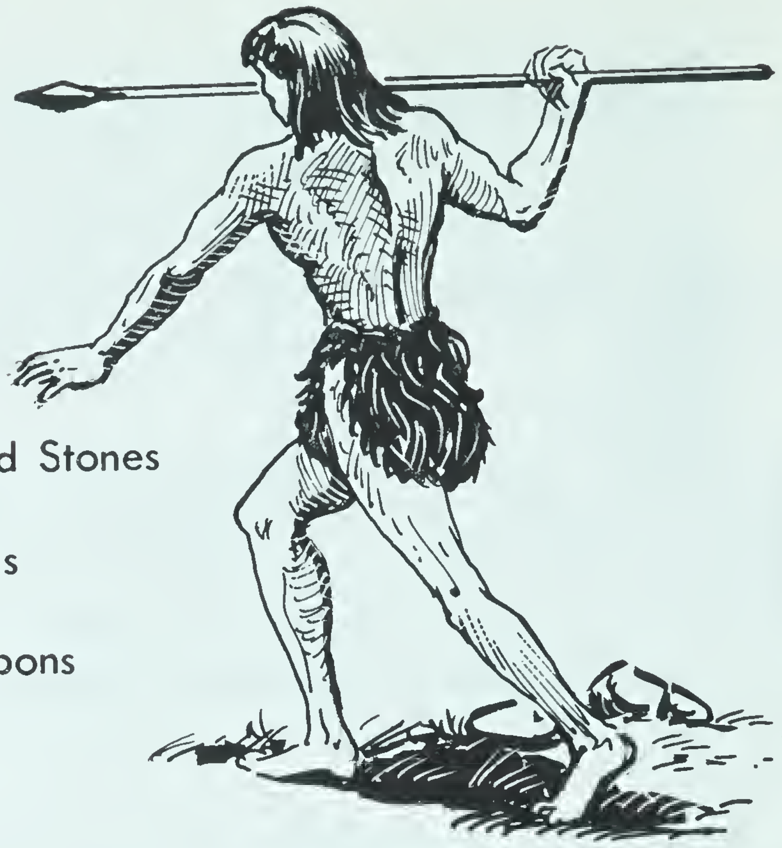
The new

TODAY WE HAVE MACHINES TO GENERATE HIGH SPEED, OTHERS to exert tremendous force, still others to perform delicate operations, and to produce articles in great quantities.

Simple machines can be operated without special attention to the materials of which they are made. But as compound machines became more powerful and complicated, man found that friction, bulk, and wear could be reduced. To do this he had to build machines of suitable materials. In the automobile, for instance, different parts are made of different metals, and several kinds of grease and oil are used to lubricate them.

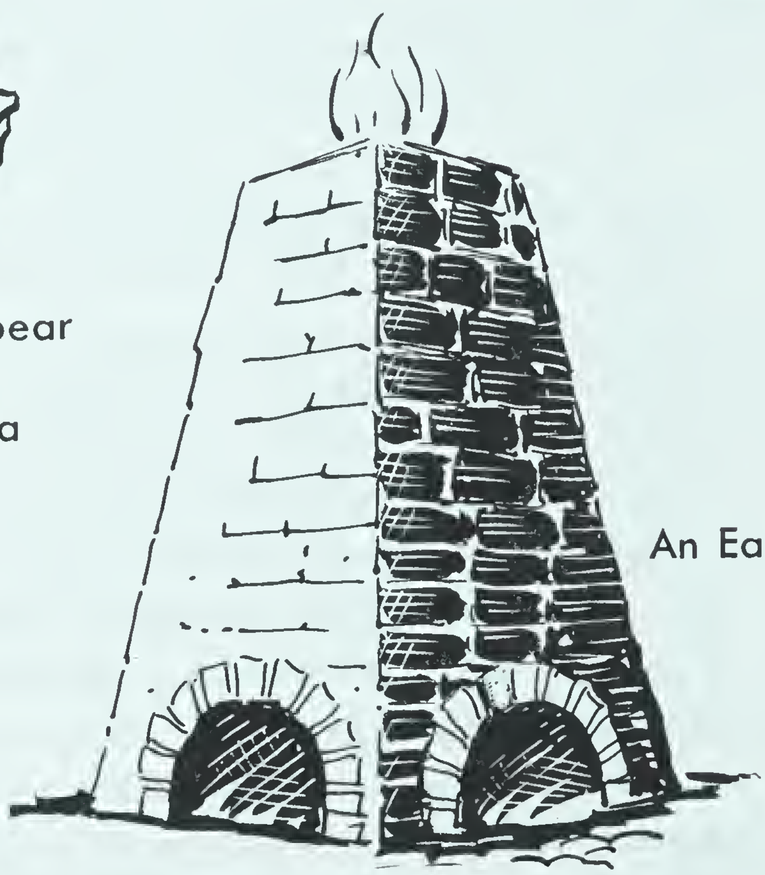
Compound machines driven by powerful engines need special ways to transfer force from one moving part to another. The mechanical devices used are many, including shafts, belts, gears, and chains.

All these mechanical advances have been used in developing the modern locomotive, automobile, airplane, and steamship. They have been equally important in the growth of all industries that use machinery. But the six simple machines will always keep their fundamental importance, no matter what future advances may be. And friction will always have to be taken into account.

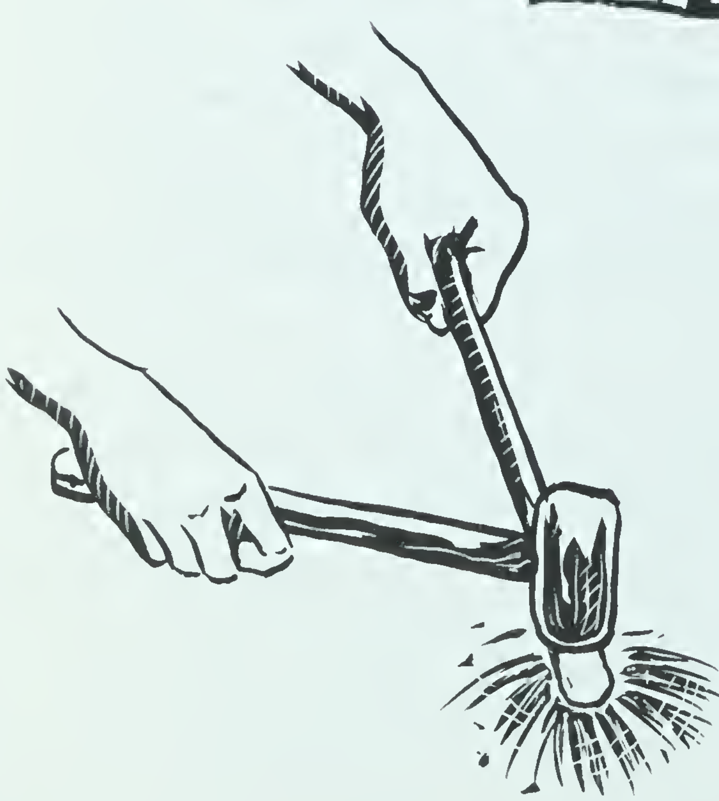


Early Man Used Stones
for Tools
and Weapons

A Helmet and Spear
of The Bronze Era



An Early Blast Furnace



Steel Tools From
an Early Blast Furnace

UNIT 14

How has man learned to use metals and machines for power?

DISCOVERY AND PROGRESS

ANCIENT man found purely by accident that when he melted certain rocks he got a new material from them. In time this material came to be known as *metal*. It was quite different in appearance from the original rocks. Eventually he learned that he could make crude weapons and tools with this metal. Thus the Age of Metals began, and we are still living in it.

The earliest records we have of the use of metals are those of the Babylonians and Egyptians. The metal they used first was copper because they could get it easily in its pure state. But copper tools were soft and would not hold an edge. Then these ancients

found that if they added a small amount of tin to the copper they got a new metal which was harder. Also, they could mold it into any shape they wished. They called this new metal bronze. As early as 2,000 B.C. both the Babylonians and the Egyptians began to replace copper with bronze. This was the beginning of the Bronze Era of the Age of Metals.

By a slow process, early man was able to get a crude, pasty kind of iron. He mixed alternate layers of iron ore and charcoal in a hole in the ground, lighted the charcoal, then fanned the flames with a hand bellows. This was the first blast furnace. Later, he used a forge. About 1340, coal and coke were used instead of charcoal and molten pig iron was first produced in the lower Rhine Valley.

Sir Henry Bessemer of England got the idea that he could burn out some of the impurities in pig iron. He used a crucible that had holes in the bottom through which he forced hot air with a powerful blower. He poured half a ton of pig iron into the crucible and started the flame and burner. And what did he get? Steel—in such quantity and so cheap that the Steel Era began.

The use of machines would not have been possible if man had not learned to get new and better fuels. They supplied the heat in the metal industries. They also furnished the energy to run the machines.

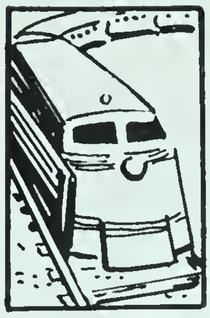
As long as wood was plentiful and easy to get, man did not need other fuels. Wood was used in England until the forests began to dwindle and then the people began to mine coal.

When James Watt was a boy, he examined a model of a steam engine which had been invented to pump water from coal mines. He studied it and shortly afterwards greatly improved it, so that it could pull trains and operate large machines.

Later, in 1829, George Stephenson became interested in the steam engine and built a larger and stronger one. It could pull eight railway cars, weighing 30 tons, between the coal mine and the shipping station, nine miles away. Thus, the steam engine came into general use.

Oil is another fuel which has become useful in running engines. There is an old story about an Indian squaw who found oil in America long before Columbus discovered it. She lived near a stream called the "water of many colors." She dipped her blanket in the stream and found that it was not wet with water, but with something which would not evaporate from her blanket. In 1854 two men rented this very region to explore for oil. They drove wells and soon got large amounts of petroleum.

The next step was the discovery that you can make gasoline from petroleum. So, instead of having to heat water with coal to change it to steam, gasoline was exploded in the cylinders of an engine. The first gasoline engines were built by men in France and in Germany. It was first used in our automobiles about 1890, and in airplanes some years later.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What is an ore? **2.** How do we extract metals from their ores? **3.** How is pig iron made? **4.** How is steel made? **5.** What are alloys? **6.** For what purposes do we use solder? **7.** How is steam used to operate a steam engine? **8.** What is the source of energy in a gas engine? **9.** How are engines used to run boats, trains, automobiles, and airplanes? **10.** Why is any country dependent on its sources of ores and fuels?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

alloy . . . . (*al*-loy), a substance which contains a uniform mixture of two or more metals, usually formed by melting the metals together.

carburetor (*kar*-buh-ray-tor), a device for mixing gasoline vapor with air before exploding it in the cylinders of a gas engine.

crucible . . (*kroo*-sih-bul), a hollow container, such as the one at the bottom of a blast furnace which receives the molten metal.

eccentric . (eck-*sen*-trick), a wheel with the axle off-center. In the steam engine, the eccentric operates the valves which admit steam to the cylinder and let the exhaust steam escape.

engine . . . any type of compound machine which converts heat into mechanical energy.

mineral . . any chemical element or compound occurring naturally in the earth.

ore . . . . . a compound of a metal or mineral which has undesirable substances mixed with it, and from which the metal can be extracted.

reduction . the chemical process by which oxygen is removed from a compound.

A How are metals separated from their ores?

Industries depend on useful ores. Iron oxide occurs in most red soils, as in red clay in many parts of our country. But only where the iron ore is plentiful and easy to mine does it pay to do so.

The prosperity of modern nations depends in a large way on the amount of iron ore they have and can convert into steel. In one way, we can measure modern civilization by the amount of iron recovered from iron ore.

Industry is the production of useful materials out of natural resources. The chief industries of a community often depend on the kind of rock, or ores, found there. For example, useful ores form a mining center; building stone, a quarrying center; good soil (weathered rock), a farming community; and coal, a mining and manufacturing center. Heat is necessary both to run machinery and to purify and refine the ores.

Metals are separated from their ores by roasting and reduction. Ores are compounds of a metal or mineral mixed with undesirable substances from which they must be separated. Thus, iron ore is usually an oxide of iron mixed with sand and other impurities which must be removed to get the pure iron. Some common ores are: the oxides, carbonates, and sulfides of iron, copper, lead, and zinc.

We commonly treat ores by two processes: (1) *roasting;* and (2) *reduction.* When carbonates are heated in the air, or *roasted,* carbon dioxide

Fig. 14-1. Open-pit mining is used when ore is concentrated near the earth's surface. Most of our iron comes from such mines.

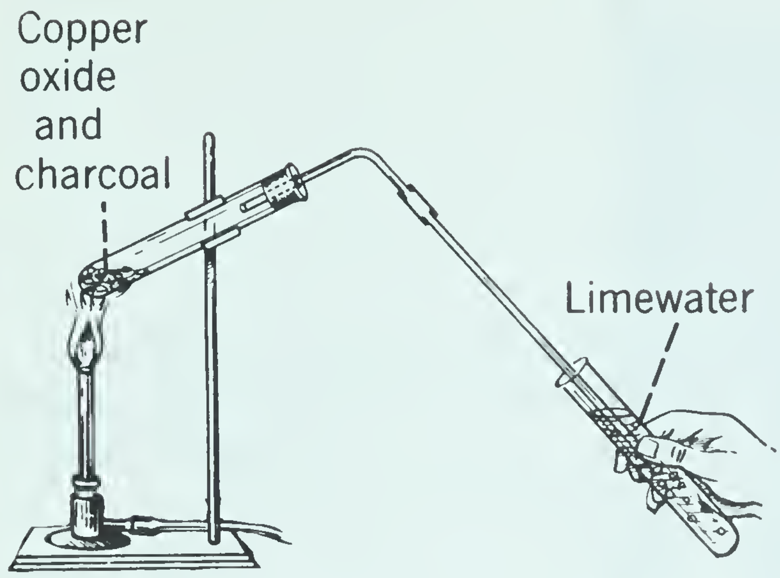


Fig. 14-2. The process of reduction separates the metal in ore from the oxygen.

is released. An oxide of the metal is left behind. For example, zinc carbonate plus heat gives us zinc oxide plus carbon dioxide. Then we must *reduce* the zinc oxide to get pure zinc. When sulfide ores are roasted, sulfur dioxide is released.

The resulting oxide of the metal must then be reduced to get the pure metal.

Reduction is the chemical process by which oxygen is removed from a compound. When we heat an oxide, such as copper oxide, with carbon in the form of coke or charcoal, reduction occurs. The carbon combines with the oxygen to form carbon monoxide or carbon dioxide. The pure metal remains.

DEMONSTRATION

Put a small quantity of copper oxide or lead oxide in a hard-glass test tube as in Fig. 14-2. Add enough powdered charcoal to cover the oxide. Arrange the apparatus to pass the gas formed through

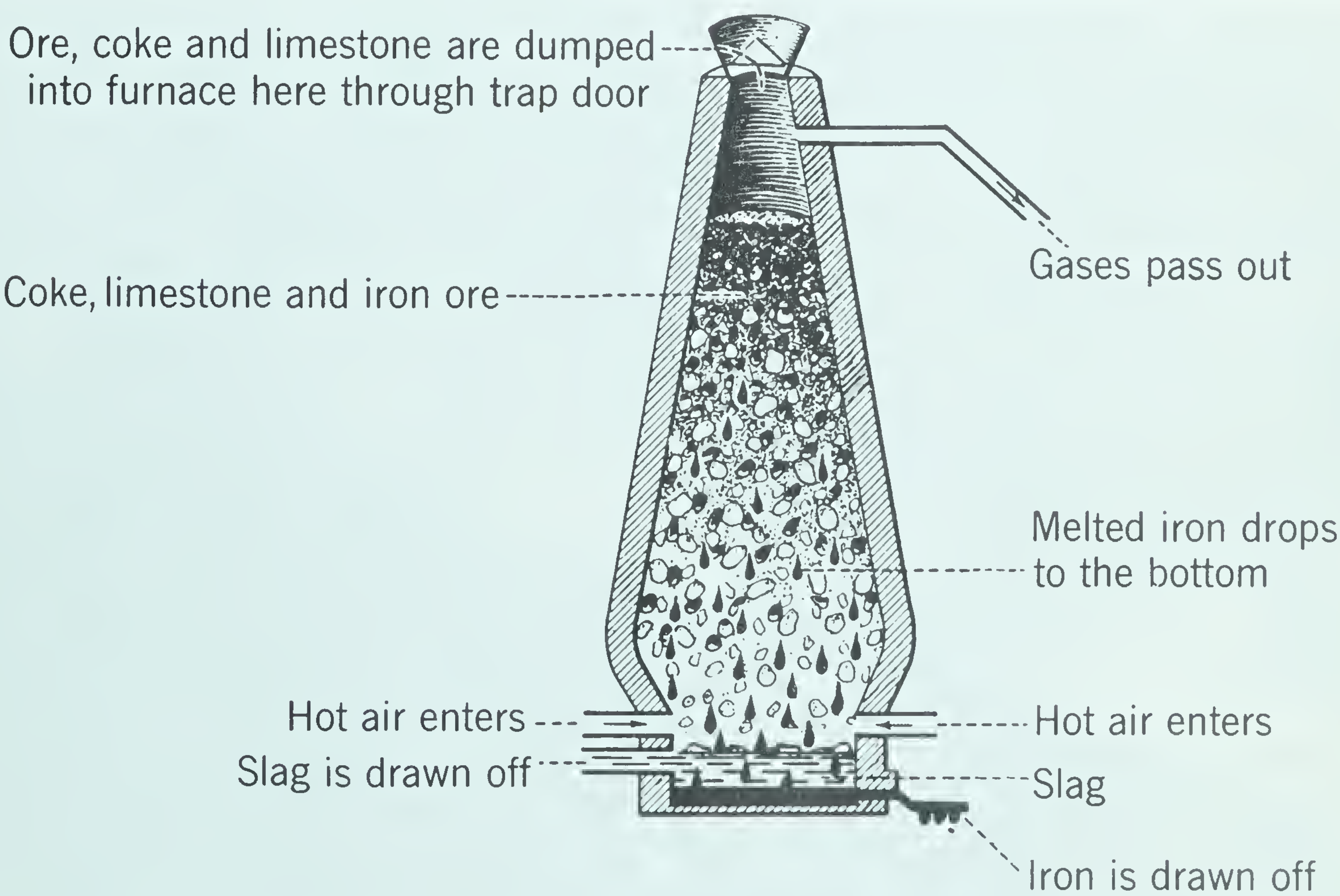


Fig. 14-3. High temperatures in blast furnaces are necessary to separate iron from its ores.

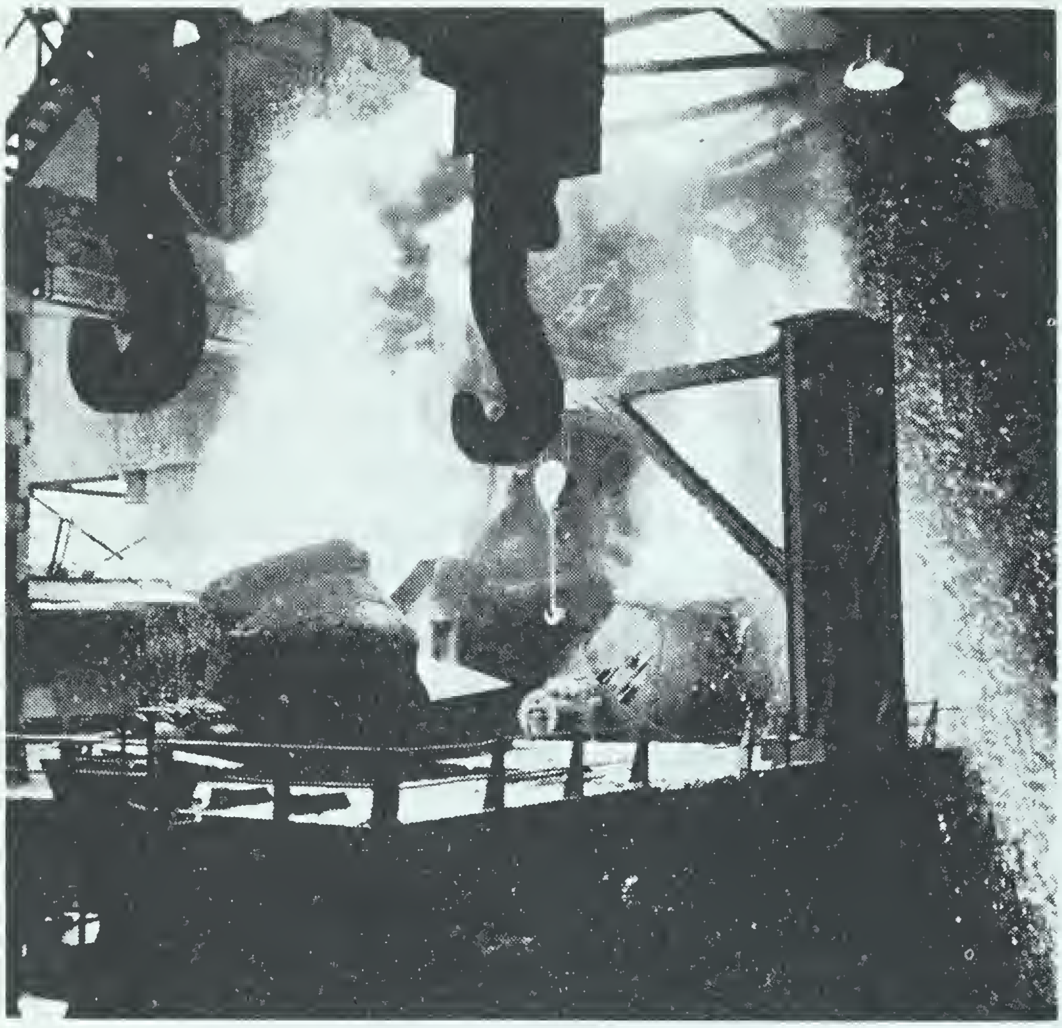


Fig. 14-4. Here you can see a Bessemer converter in operation as it receives a charge of molten blast-furnace iron.

limewater as shown. Heat the mixture of charcoal and oxide for several minutes with a hot flame. When the test tube has cooled, pour its contents into a large beaker. Add water and shake thoroughly. Then pour off the liquid. What collects at the bottom of the beaker? What has the carbon in the charcoal removed from the oxide? What gas passed through the limewater? What do we mean by the term reduction?

A blast furnace is used to separate iron from its ores. We can separate iron from iron oxide by reduction, but it requires intense heat. Only a blast furnace can furnish the high temperatures necessary.

In a blast furnace the iron ore is mixed with coke and limestone. After these are mixed, a terrific blast of hot air is blown into the furnace. The coke (carbon) unites with the oxygen from the iron oxide and forms carbon monoxide or carbon dioxide. The gases escape through openings in the top of the furnace. As a result of this heating, the iron melts and settles to the bottom of the furnace, as shown in Fig. 14-3.

The limestone unites with the impurities and forms a liquid called *slag,* which is lighter than iron and floats on it. The iron is drawn out from the bottom of the furnace, run into molds,

CHEMICAL CHANGES IN A BLAST FURNACE

1. Limestone (heated) yields lime and carbon dioxide.
2. Coke (carbon) heated with iron oxide yields iron and carbon dioxide.
3. Lime heated with sand yields slag.
4. Carbon dioxide heated with coke yields carbon monoxide.

and allowed to cool to its solid form. The iron from a blast furnace is called *pig iron.* The slag is drawn off at the side of the furnace. It is usually discarded as a waste material.

The carbon monoxide will burn and is used as a fuel to produce heat.

Pig iron is not pure iron. It contains from 92-95% of iron and some impurities. However, it is remelted in a foundry and formed into useful articles. Then it becomes *cast iron.* Cast iron is used for making parts of machines or heavy tools not subject to sudden strains.

The Bessemer process changes pig iron into steel. This consists mainly of removing most of the impurities in pig iron by oxidation. The Bessemer process takes place in a large furnace known as a *converter.* Here the pig iron is changed into steel by blowing hot air through it while it is in the molten condition.

The open-hearth furnace produces most of the steel used in this country. It is slower than the Bessemer process, but produces larger batches of steel. Because it is slower, the quality of the steel can be more carefully controlled.

Different kinds of steel are made by mixing the molten iron with various elements like silicon, tungsten, carbon, and manganese. A substance formed by mixing two or more metals in this way is called an *alloy.* Each alloy has special properties that make it useful for some particular purpose.

REVIEW QUESTIONS

1. What is an industry? **2.** Name the industries in your locality that depend on

Fig. 14-5. This man is taking a sample of the molten iron from an open-hearth furnace. Iron samples must be tested frequently in the making of steel.

raw materials found in the ground. **3.** What is an ore? **4.** What two methods are used to purify ores? **5.** How is pig iron made? **6.** How is cast iron made? **7.** How is pig iron converted into steel? **8.** What is an alloy?

B How are air blasts used to produce high temperatures?

Compressed gases are used to produce blasts. When iron and copper and other metals are separated from their ores, we have seen that the temperature produced must be high enough to melt the metals. In the blast furnaces and the Bessemer converter, hot blasts are blown through the contents. The fires that produce the hot blasts are in large stoves outside the furnaces. If a blast of air is used, the rate of oxidation is increased and the temperature rises. Hot blasts may be produced by forcing air over or through a hot fire. The air is heated as it is forced through the fire. This method gives a high temperature without having the products of combustion carried over with the blast. If the impurities were carried into the blast furnace with the hot flame, they would unite with the iron and form an impure grade of cast iron. Sometimes oxygen is mixed with the hot air before it is blown into the blast furnace. This mixture of oxygen and air reduces the ore faster than a blast of hot air alone.

DEMONSTRATION

With a blowpipe produce a blast of air directed against a small flame of a Bunsen burner with air openings closed. Make a small hole in a block of charcoal or plaster of Paris. Put different metals, one at a time, on the block and direct the tip of the flame against the metal as shown in Fig. 14-6. What metals can be melted with the blowpipe flame? Can you melt glass this way?

A blast is formed when air, under pressure greater than normal atmospheric pressure, is mixed with a fuel when it is being burned. The larger the quantity of fuel burned and the greater the air pressure, the higher the temperature will be.

In oil burners, the oil is vaporized by a blast of air from the fan. In this way we can burn cheap oils and produce high temperatures without getting smoke or soot.

In the blow torch, which is used by plumbers and electricians, air is forced into the tank under pressure. This pressure forces out the gasoline used as fuel. It is mixed with air to form a spray. Usually the pipe or jet through

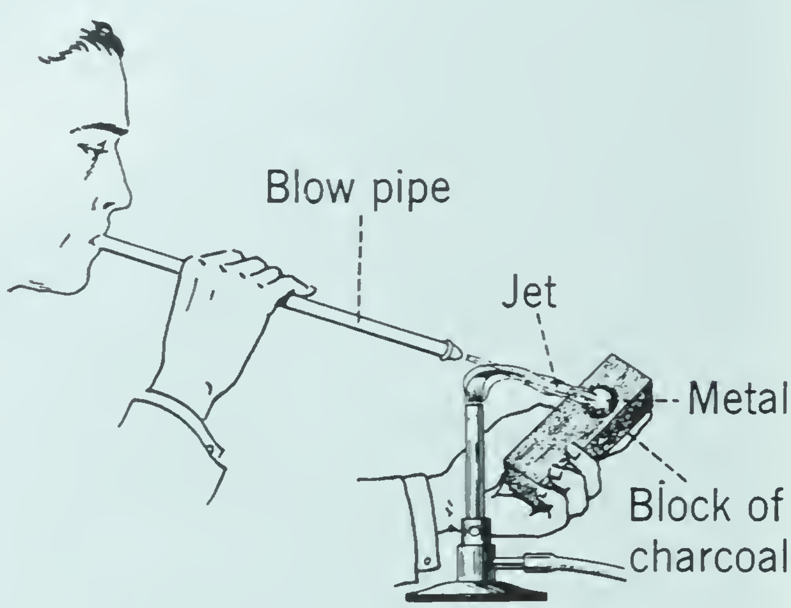


Fig. 14-6. With a blowpipe flame, you can produce a hot blast that will melt metals.

which the fuel is forced is heated before the burner is lighted. The heated tube helps to vaporize the gasoline. The mixture of air and gasoline burns with a hot flame. More air is pumped into the tank as needed.

If high temperatures are to be produced by oxidation, air and fuel must be mixed thoroughly before burning.

If we use oxygen under pressure in place of air, the temperature can be greatly increased. This is especially true if we use a combustible gas like *acetylene* (ah-*set*-ih-leen) as a fuel. A temperature of 3,700° C. may be reached in the oxyacetylene flame. Oxyacetylene torches are used to cut iron and steel rails or to cut steel beams apart in wrecking buildings. They are also used for welding.

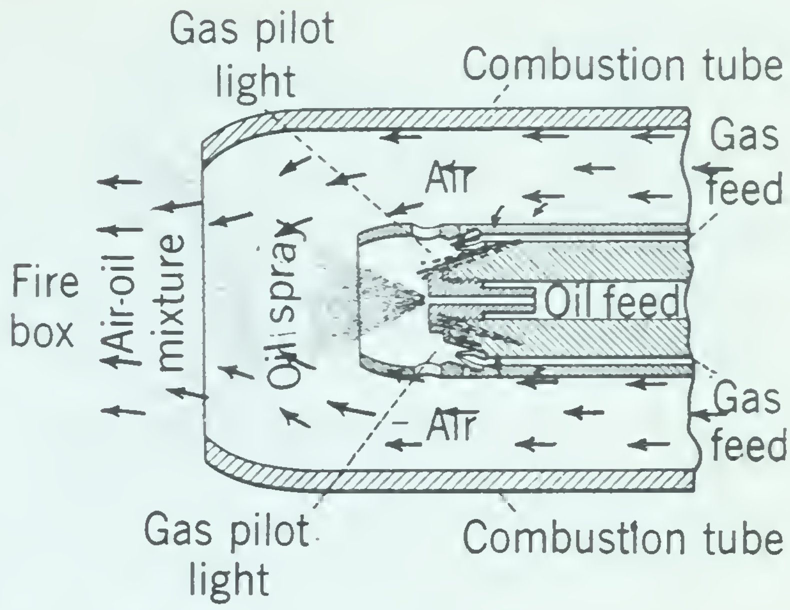


Fig. 14-8. In an oil burner, the oil is vaporized by blowing a blast of air through it. It is then mixed with air and burned.

Solder is a mixture of lead and tin which melts at low temperatures. If you vary the amounts of lead and tin in the mixture, the melting point of the solder (*sod*-der) will be different. This makes possible different kinds of

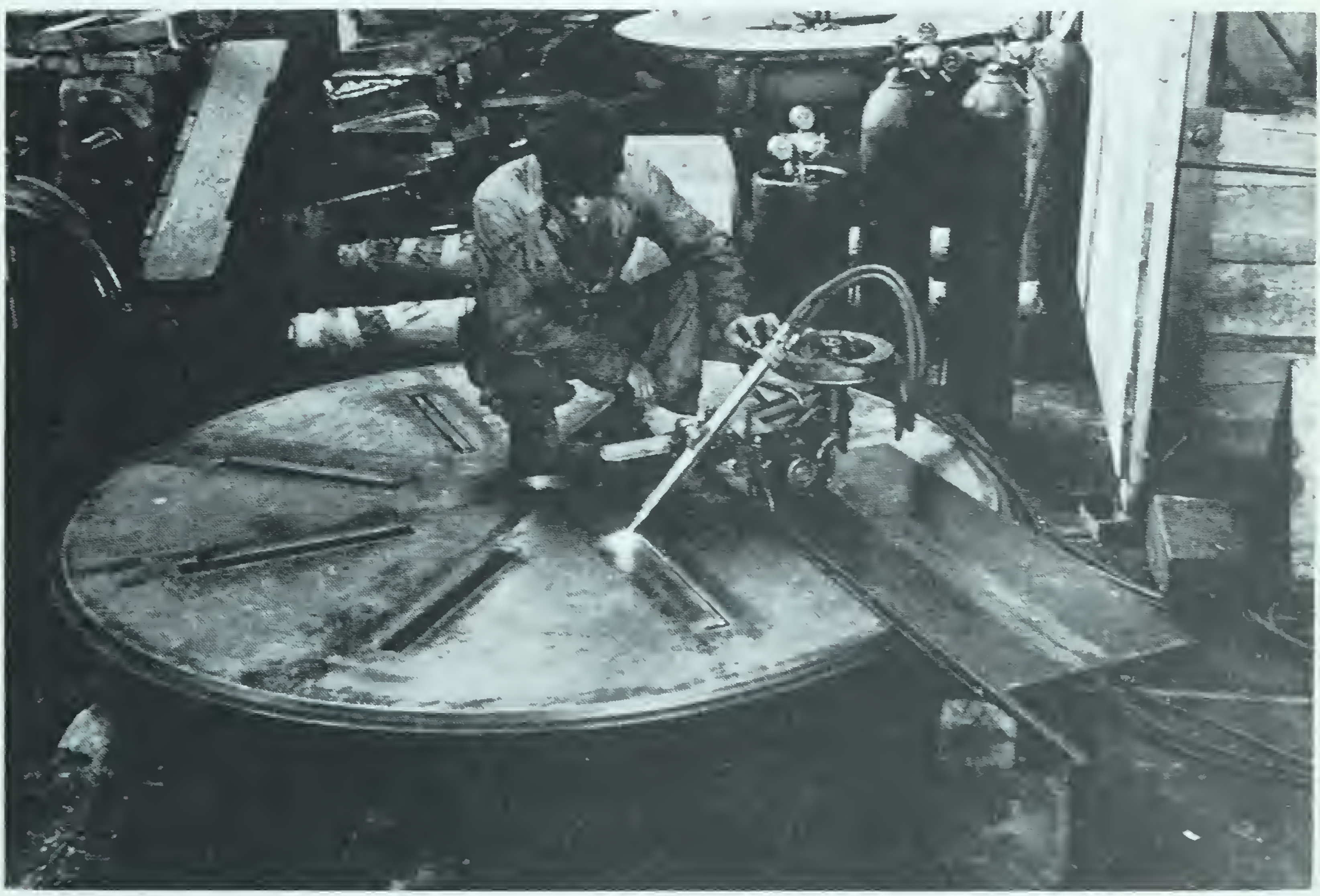


Fig. 14-7. Oxyacetylene torches, whose temperatures are estimated to be from 3,400° C. to 3,700° C., are used to cut metals.

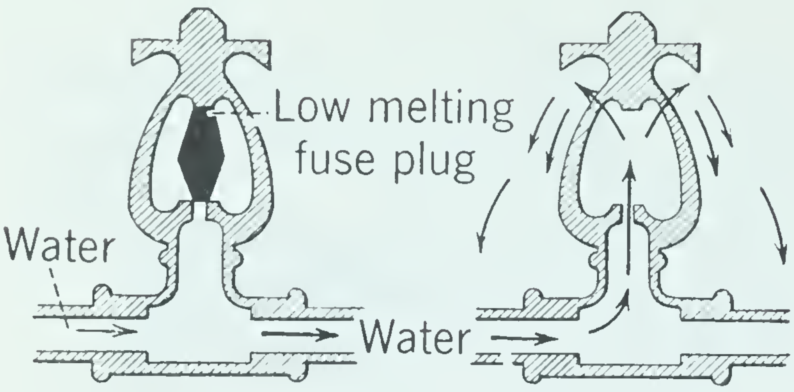


Fig. 14-9. In automatic sprinkler systems, fuse plugs melt when fire occurs. This lets the water flow out of the pipes to put out the flames.

solder that will melt at different temperatures. If you make a solder of equal parts of these two metals, the mixture has a melting point of 180° Centigrade, which is less than that of either metal alone.

We use solders to join metals that melt only at a high temperature. Less heat is needed to melt the solder than to melt the metals joined. Sprinkler systems for fire protection depend on the melting of solder plugs by the fire. The water then rushes out of the plugs and puts out the fire. See Fig. 14-9.

Metals may be welded together by heating and pounding. We have learned that heat is a form of molecular motion. When you heat a substance, the movement of its molecules becomes more vigorous. The spaces between the molecules are enlarged, and the molecules begin to move about freely. Soon, the entire mass becomes a liquid, and if you heat it further, the molecules will fly off into space as a gas.

Some metals cannot be welded by mere heating, but many of them can. So, we use the property of *malleability* (mal-ee-ah-*bill*-ih-tee) to work them, when heated, into whatever form we wish. *Malleability* means that a metal can be molded into shapes by pressure.

Wrought iron is practically pure iron, and it is easily welded because, when heated, it is softer than steel. In that form you can pound it into any shape.

REVIEW QUESTIONS

1. How is air mixed with the gas in the Bunsen burner? With oil in the blast lamp? With oil in the oil burner? **2.** How is a hot-air blast produced for a blast furnace? **3.** How are blasts produced in the blow torch? **4.** How are high temperatures produced by using oxygen instead of air? **5.** How is the blast produced in the oxyacetylene torch? **6.** What are the main differences between soldering and welding?

C Why are coal, petroleum, and wood such important raw materials?

A ton of coal provides the raw materials for thousands of different products. Without coal the life blood of our country would stop flowing. Public utilities could not operate. Light, heat, and power would fail and the wheels of industry would cease to turn.

Did you ever stop to think that bituminous coal is used to produce three other fuels: synthetic petroleum, cooking gas, and carbon? Some of the products obtained from one ton of coal are included in the list on the following page.

I. Heat and power if burned in a furnace
II. Chemical products, if not burned as fuel
  A. Gas liquor, 6.5 lbs.
    1. Ammonium chloride for batteries
    2. Ammonium nitrate (an explosive)
    3. Ammonium sulfate (a fertilizer)
    4. Ammonia gas for refrigeration
  B. Fuel, gas, 440 lbs.
    1. Gas for lighting and heat
  C. Coke, 1,433.5 lbs.
    1. Black paint
    2. Black pigment
    3. Carbon electrodes for electric arc lights
    4. Briquets for fuel
    5. Graphite for lubrication (after electric furnace treatment)
  D. Tar, 120 lbs.
    1. Pitch for paving, roofing, waterproofing, etc.
    2. Heavy oils for wood preservation
    3. Benzol for improving motor fuels
    4. Naphtha for cleaning
    5. Aniline dye for coloring cloth
    6. TNT for explosives
    7. Picric acid (an explosive)
    8. Aspirin
    9. Carbolic acid (a germ killer), also used in making plastics
    10. Paraffin
    11. Photo developer, etc.

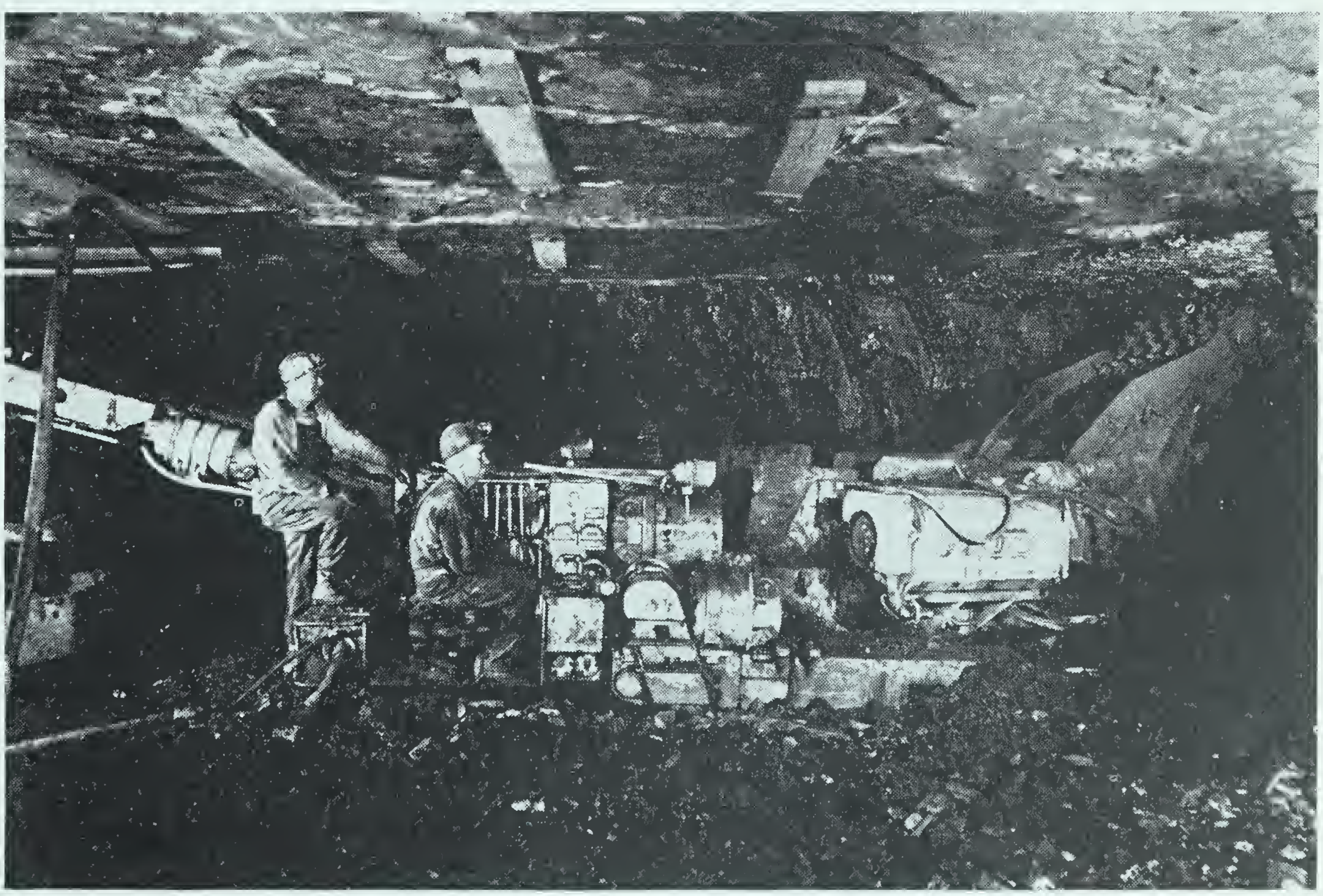


Fig. 14-10. The "Continuous Miner" eliminates most of the hand labor in coal mining.

No wonder coal is sometimes called "black gold."

Coal, when burned, releases a tremendous amount of heat energy. A pound of bituminous coal will set free 14,000 Btu's of heat when completely burned. One Btu of heat energy is equivalent to 778 foot pounds of work. One pound of coal when burned can do work equivalent to 14,000 x 778, or 10,892,000 foot pounds. How long would it take a man to do the same quantity of work if he does 80 foot pounds of work per second? Actually it would take him 4 days, working 8 hours each day.

Our heating stoves and engines are not very efficient. Our best steam engines have an efficiency of about 20% and our best heating systems seldom exceed 75%. Most of them are not more than 50% efficient. Better ways of burning coal are being developed constantly. This means a higher efficiency and more useful heat energy from the same amount of coal burned.

A gallon of petroleum yields many useful products when it is distilled. Naphtha, benzine, and gasoline are boiled out first, at the lowest temperatures. Next, kerosene is evaporated, then fuel oil, the light lubricating oils, and finally the heavy lubricating oils. The product left in the stills is petroleum coke.

Petroleum provides an enormous amount of heat energy. One pound of petroleum yields 19,000 Btu's of heat energy when completely burned. In work, its equivalent is 19,000 x 778 or 14,782,000 foot pounds. As one oil company advertised: "A gallon of petroleum contains 90,000,000 foot pounds of work." How long would it take a man to do work equivalent to that of one gallon of petroleum if he worked at the rate of 80 foot pounds per second?

Petroleum provides materials for many products. Raw materials from petroleum are used by chemists to make many useful products. Among

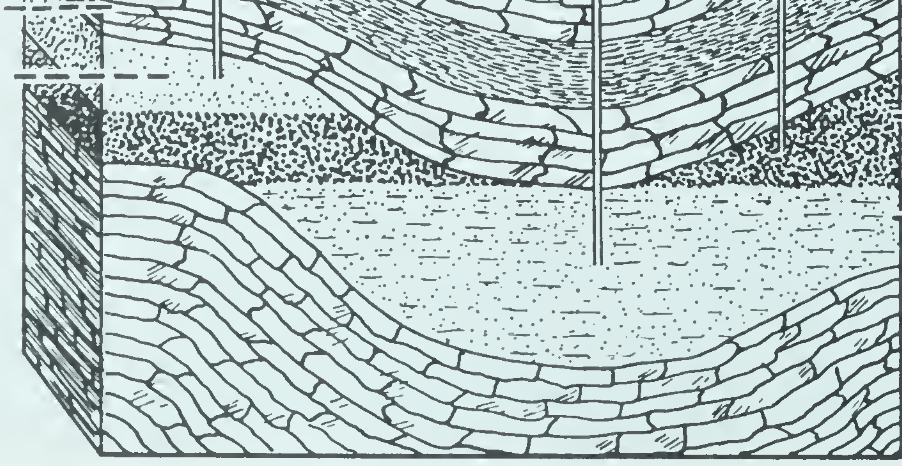


Fig. 14-11. Gas and oil are found only in certain types of rock formations.

Fig. 14-12. This photograph shows a drill bit used in drilling for oil. It is being centered over the hole at the base of an oil derrick.

them are: chewing gum, cosmetics, TNT, carbon black, paints and varnishes, wax, naphtha, benzine, gasoline, fuel gas, soap, synthetic rubber, and various plastics. Continued research will doubtless lead to other products from petroleum in years to come.

Wood provides many useful products. The use of wood as a fuel is gradually decreasing. Coal and petroleum are better sources of heat energy. However, many useful products are made indirectly from wood. A few of these are: paper, wood alcohol, acetic acid, acetone, resins, turpentine, rayon, explosives, and charcoal. Wood is also used for lumber, furniture, and for many types of construction. What substitutes for wood can you think of?

Fuels in different forms help keep us warm, cook our foods, give us light, produce chemical changes, get metals

Fig. 14-13. In many sections of the country, farmers depend on the wood from forests for a cheap and continuous supply of fuel for their needs.

from their ores, and furnish energy to run our engines and other machines.

Conservation is our duty as good citizens. Coal, petroleum, and wood are among our many natural resources. They are ours for the taking, but they will not last forever. It is our duty to use them carefully, and see that they last as long as possible. Wood is replaceable because we can plant new forests. But coal, petroleum, and natural gas will eventually be used up.

We must conserve all three of these and use them wisely. And we must see that conservation of our natural resources is practiced by all.

REVIEW QUESTIONS

1. Why is coal important? **2.** What are some of the principal products derived from coal? **3.** What industries are dependent on petroleum? **4.** What industries are dependent on coal? **5.** In what ways do fuels aid man? **6.** How much heat energy does one pound of coal contain? One pound of petroleum? **7.** Why must we conserve our natural resources?

D How is energy in fuels changed into energy of motion in the steam engine?

The volume of steam is much larger than the volume of water from which it is formed. Scientists have determined that when one cubic inch of water is changed into steam without confinement, the steam occupies about one cubic foot of space. This is nearly 1,700 times the volume of the water

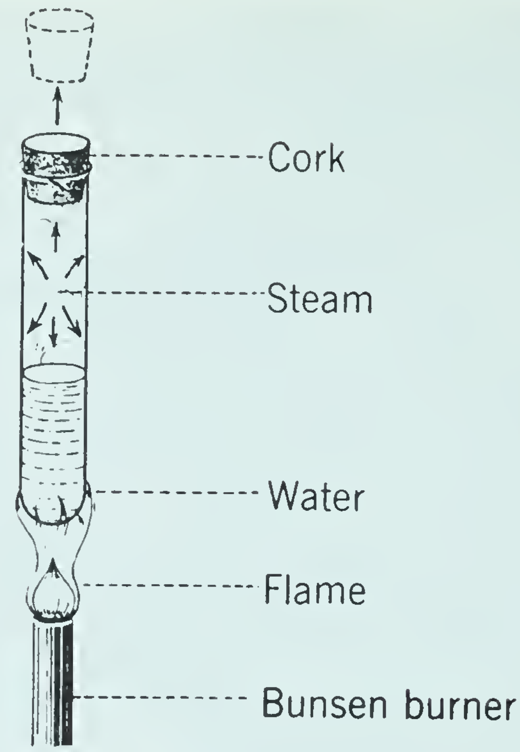


Fig. 14-14. The expansion of steam forces the cork out of the test tube.

used. When the water is converted into steam in a confined space, the pressure increases and is exerted in all directions. As the pressure in the boiler increases, a higher temperature is needed to make the water boil, and there is more molecular motion.

In the steam engine we burn fuel in a boiler to change the water into steam under pressure. Coal or oil is usually the fuel.

DEMONSTRATION

Heat a little water in a test tube which is rather loosely stoppered (see Fig. 14-14). Be careful not to stopper the tube too tightly. Keep the test tube at arm's length and pointed away from your body. Result? What is the cause of the explosion? Why is the cork forced out? How much space was occupied by the steam just before the explosion? In what condition was the steam? What was it that caused the noise of the explosion?

(NOTE. The teacher must try out this demonstration carefully before class.)

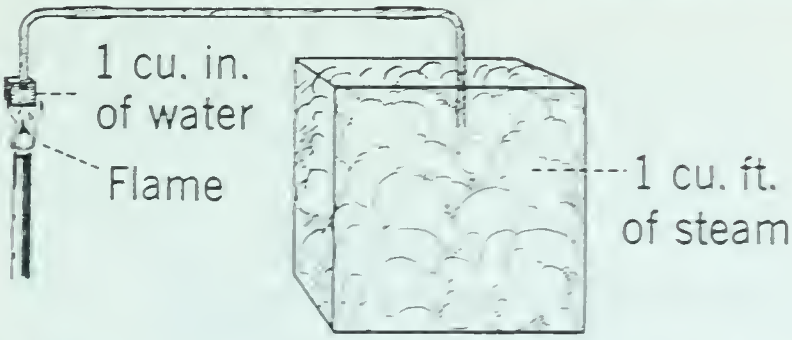


Fig. 14-15. One cubic inch of water makes about one cubic foot of steam.

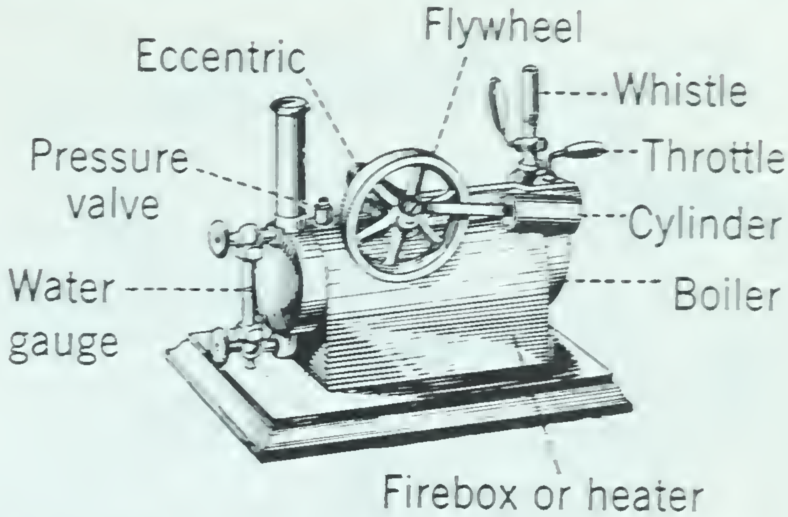


Fig. 14-16. This working model illustrates the principle of a reciprocating steam engine.

The problem in a steam engine is to use the pressure of the steam to cause circular motion. This has required the thoughts, energies, and inventive ability of many scientists. They have developed two types of engines to do this. One, the *reciprocating* (re-*sip*-row-kate-ing) *engine*, has a piston that travels back and forth in a cylinder. The other is the *steam turbine*, which works like the water turbine (studied in Unit 7) except that it uses steam under pressure instead of moving water.

PUPIL ACTIVITY

Examine a toy reciprocating steam engine. Find the boiler, steam pipe, steam chest, piston rod, cylinder, water gauge, safety valve, eccentric, and crank shaft (see Fig. 14-16). Partly fill the boiler with water, heat it, and get up steam. Where does the steam come out? What makes the piston move back and forth? How is the piston movement changed into a circular motion? How does the eccentric work? What is the use of the flywheel? Why are certain portions of the wheels of locomotive engines heavier than other portions?

A reciprocating steam engine produces motion by the expanding force of steam. Steam is produced under high pressure in a boiler and goes into a steam chest. Then it enters a cylinder and expands, first on one side, then on the other side of a piston. This expansive force causes the piston to move back and forth. A crank changes the back and forth motion of the piston into the circular motion of the shaft.

A wheel with the axle off-center turns with the rotating shaft. This wheel is called the *eccentric* (eck-*sen*-

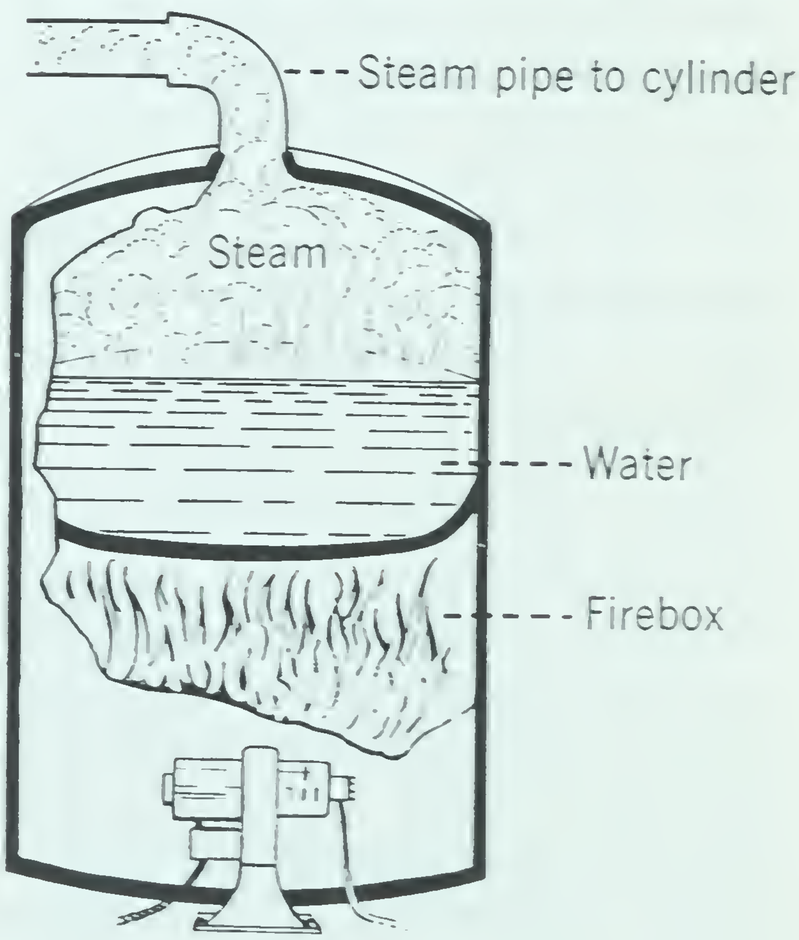


Fig. 14-17. The more steam that is produced, the more the pressure increases.

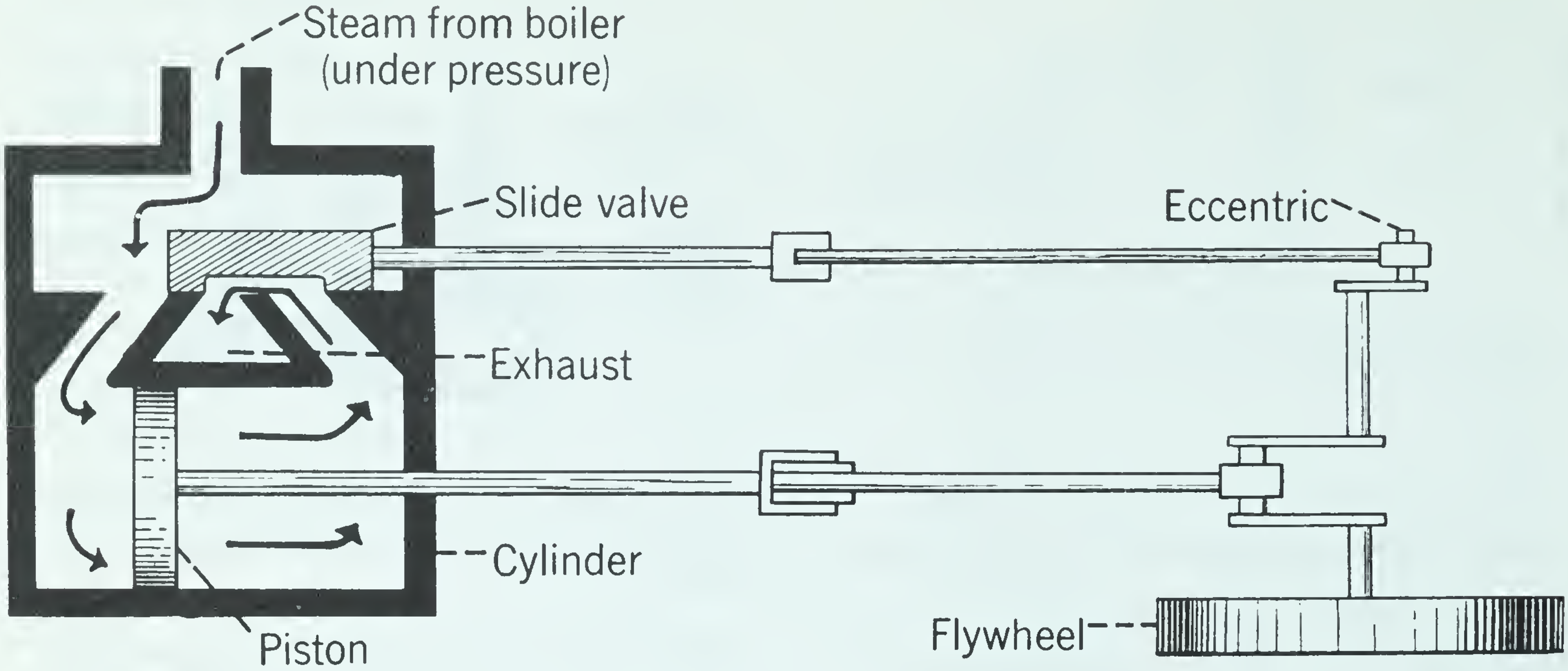


Fig. 14-18. In the steam engine, the pressure of the steam on the piston causes the flywheel to turn.

trick). It moves a slide valve back and forth in the steam chest to let steam enter the cylinder at just the right times (Fig. 14-18). The slide valve and eccentric are connected with the crank shaft. This connection is arranged so the opening of each *inlet port* (where the steam enters the cylinder) occurs when the piston reaches that end of the cylinder. Note that the hollow space in the slide valve is always over the *exhaust port* (where the steam leaves the cylinder). Thus, the slide valve allows exhaust steam to escape from one end of the cylinder while steam is coming in at the other end.

The waste steam is pushed out through the exhaust port when the piston moves back. Each forward movement of the piston pushes the crank shaft halfway round. Each backward movement pulls it the other halfway round, making a complete revolution or cycle of the crank shaft. This motion in turn goes to the driving wheels of the engine. What is the use of flywheels on stationary engines? The reciprocating steam engine is found in some older power plants, but its chief use today is in steam locomotives.

The steam turbine is the more modern type of steam engine. It consists of a long shaft with many blades fastened to it. This shaft is enclosed in a heavy steel case through which steam under pressure is passed. The expanding steam pushes against the blades, causing the shaft to spin rapidly.

The steam turbine has fewer moving parts than the reciprocating engine and is more efficient at high speeds, but it cannot be reversed as the reciprocating type can. Steam turbines are used in most large ships and in modern coal burning electric power plants.

REVIEW QUESTIONS

1. How is steam produced in a boiler? **2.** How many cubic feet of unconfined steam does one cubic foot of water make? **3.** What are the parts of a steam engine? What is the use of each part? **4.** Trace the energy in the fuel through all its changes in the engine. **5.** Explain why

the efficiency of a steam engine is low, usually less than 15%. Why, then, do we use steam engines? **6.** How is the back and forth motion of the piston used to get circular motion? **7.** Why do you think the boiler of a steam engine is only partly filled with water? **8.** Why is it not necessary to have a cooling system on a steam engine? **9.** Compare the reciprocating steam engine with the steam turbine as to construction, uses, and efficiency.

E How does the gas engine change the energy in fuels into energy of motion?

Liquid fuels must be vaporized before they can be burned. Gasoline is most commonly used, but kerosene is used in some engines. Diesel oil is the fuel used in our streamlined Diesel engines. All these fuels are vaporized and mixed with air before they are burned in the engines.

PUPIL ACTIVITY

Note that a Bunsen burner has one arrangement for controlling the air flow and another for controlling the gas flow. This lets it mix air and gas in just the right proportions for burning. Close the air inlet and light the burner. You now have what is known as a "rich mixture" of gas and too little air. How does the flame act? Gradually open the air inlet. What changes occur in the flame? Continue opening the air inlet until the flame "strikes back" or burns at the bottom of the tube. Describe the color of this flame. Review your study of the structure of a common gas stove burner. How is it like a Bunsen burner?

These activities help to show us that a fuel gas must be mixed with air before it will burn. An automobile has an arrangement like the Bunsen burner for mixing the gasoline vapor with air before it enters the cylinders. We call this mixer the ***carburetor*** (*kar*-buh-ray-tor).

Note in the diagram (Fig. 14-19) that a gas engine carburetor has a float chamber and a mixing chamber. The float chamber holds a constant supply of gasoline, pumped in from the gas tank, for use in the mixing chamber. The supply of gasoline must be kept at a constant level to insure a steady supply of gas. What is the purpose of the mixing chamber?

The throttle is connected to the gas pedal on the floor board of the car. It regulates how much of the gas-air mixture gets to the engine. This in turn controls the speed of the car. You can see now why "stepping on the gas" causes the car to go faster.

How does a gas engine operate? When you use the starter on your car, it causes the crankshaft to turn. This pulls the piston downward. This produces a partial vacuum above the piston. But the atmospheric pressure in the carburetor will now force the mixture of air and gasoline into this space. Note in the diagram in Fig. 14-20 that the *intake valve,* which controls the opening into the upper part of the cylinder, is open. Also note that the *exhaust valve* is closed. This exhaust valve controls the outlet into the ex-

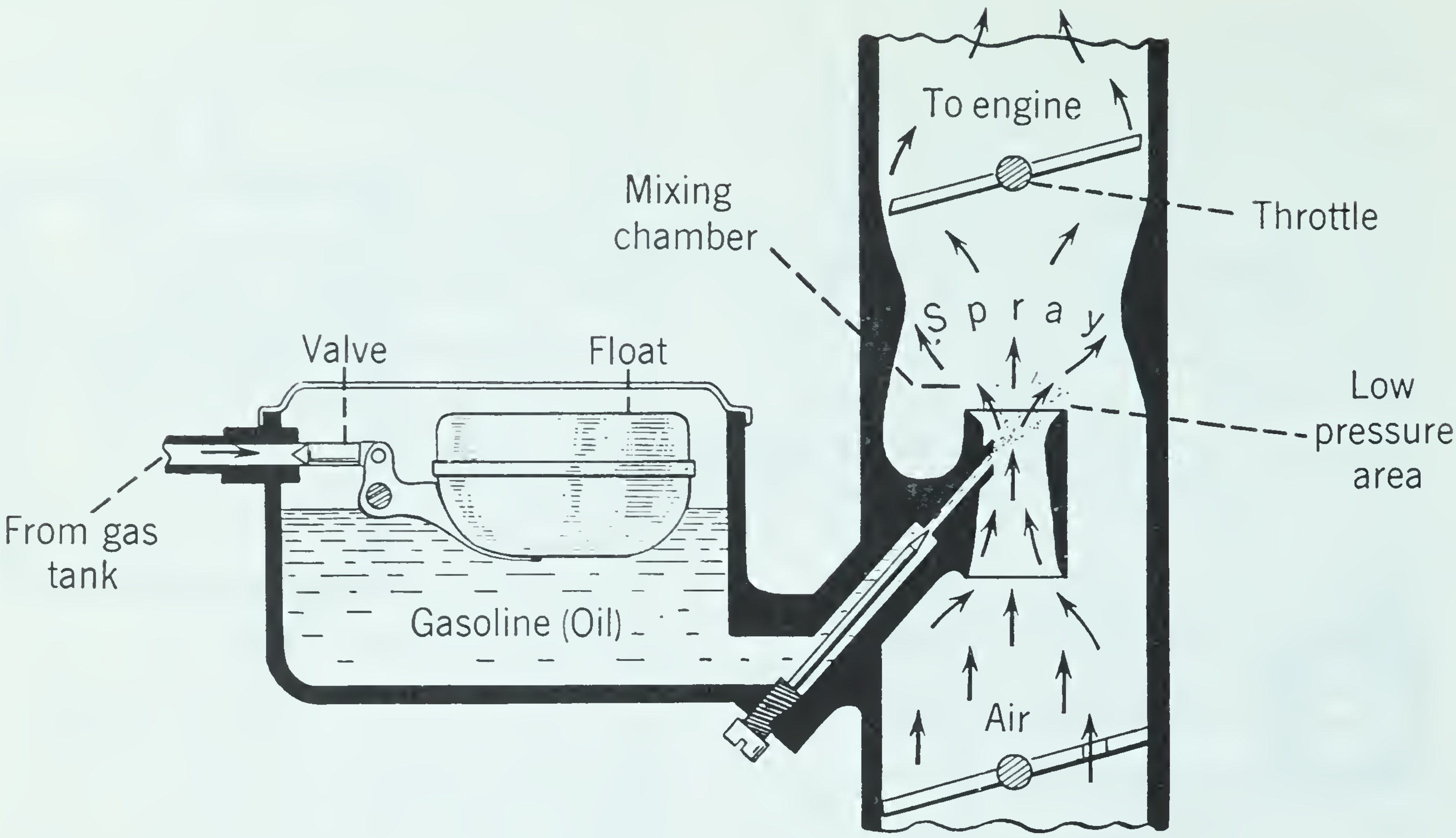


Fig. 14-19. The carburetor in an automobile vaporizes the gasoline and mixes it with air.

haust pipe. This stroke of the piston is the *intake stroke.* The term *stroke* is used to mean one movement of the piston through the cylinder.

When the piston reaches the bottom of the intake stroke, the intake valve closes and the piston starts up again. A flywheel keeps the shaft turning for a time, due to its own momentum or inertia. The exhaust valve still remains closed. The piston is pushed upward and compresses the mixture of gasoline and air into a small space at the top of the cylinder. This is called the *compression stroke.*

As the piston approaches the top of its stroke, an electric spark jumps across the small gap between the

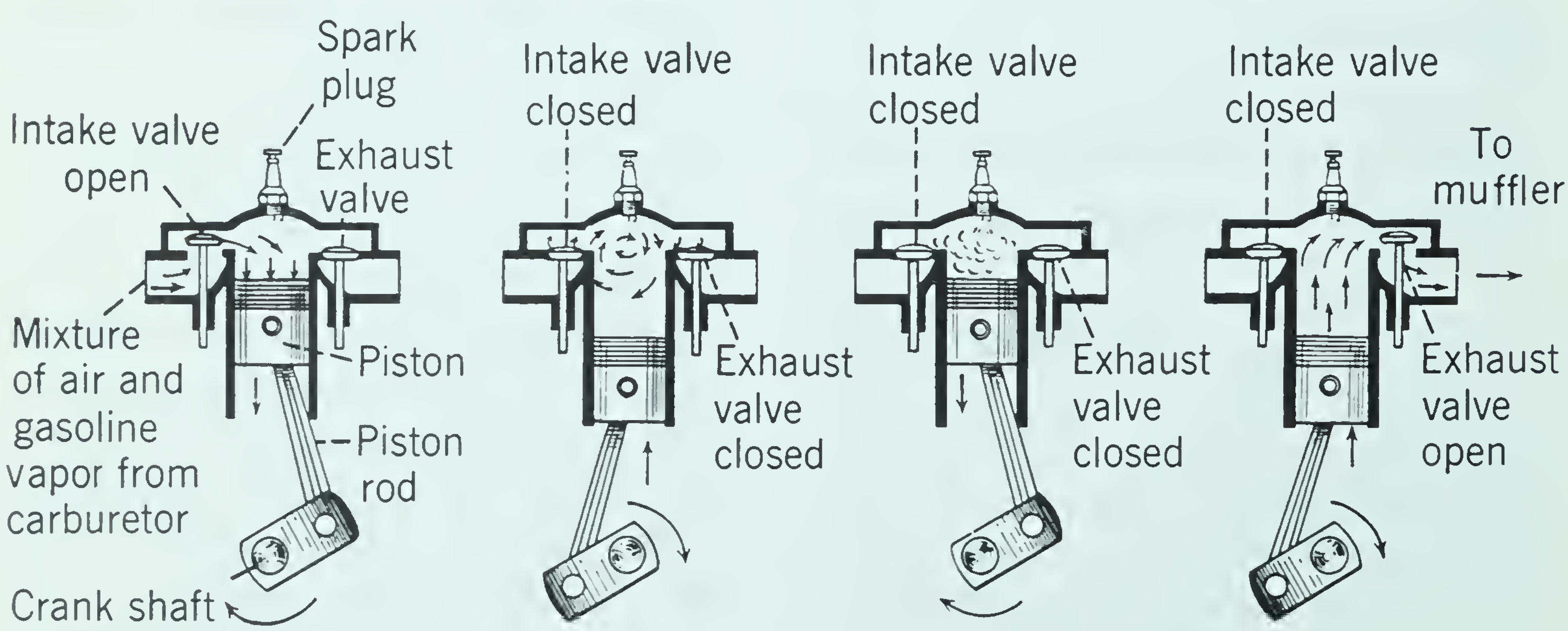


Fig. 14-20. This diagram shows the four strokes of a gas engine. During which two strokes are both intake and exhaust valves closed?

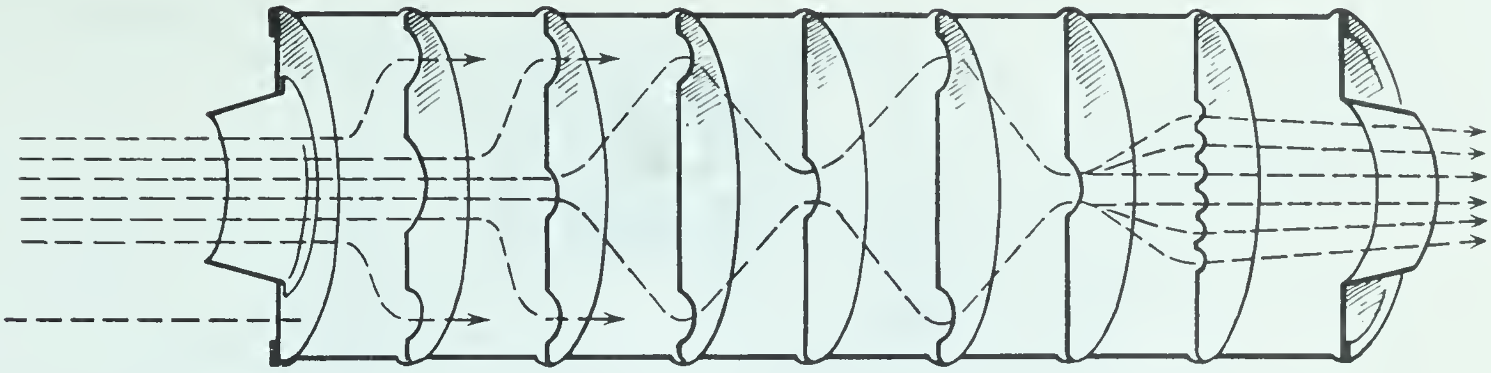


Fig. 14-21. The muffler reduces the speed of the exhaust gases so that less noise is produced.

spark plug points. This ignites the mixture and it rapidly oxidizes, expanding with great force. Both valves remain closed. This explosion forces the piston downward, turning the crank shaft. This is the *power stroke.*

When the piston reaches the bottom of the power stroke, the cylinder space is filled with waste gases. The exhaust valve now opens. As the crankshaft continues to turn, the piston is moved up and these gases are forced out through the exhaust pipe. This is called the *exhaust stroke.*

If these gases escaped directly into the open air, there would be loud popping reports as in some motor boats and motorcycles. To avoid this noise, these gases are passed through a *muffler,* which has a number of chambers within it. The gases are slowed up as they pass through these chambers, so that they meet the outer air with very little noise. See Fig. 14-21.

In a one-cylinder engine there is one explosion for every two turns of the crankshaft. In a four-cylinder engine there are two explosions for one turn of the shaft. Adding more cylinders gives more explosions for each turn and consequently more uniform power and smoother engine performance.

A gas engine is called an ***internal combustion engine*** because the fuel is burned within the engine. It vaporizes its fuel, mixes it with air, compresses the air and fuel as in a blast furnace, burns the fuel, and removes the products of combustion. The high temperature produced by the explosion expands the gases in the cylinder. It is this expansion which gives the gas engine its power.

An electric spark is used to ignite the mixture of air and gasoline. In studying induced currents, you learned

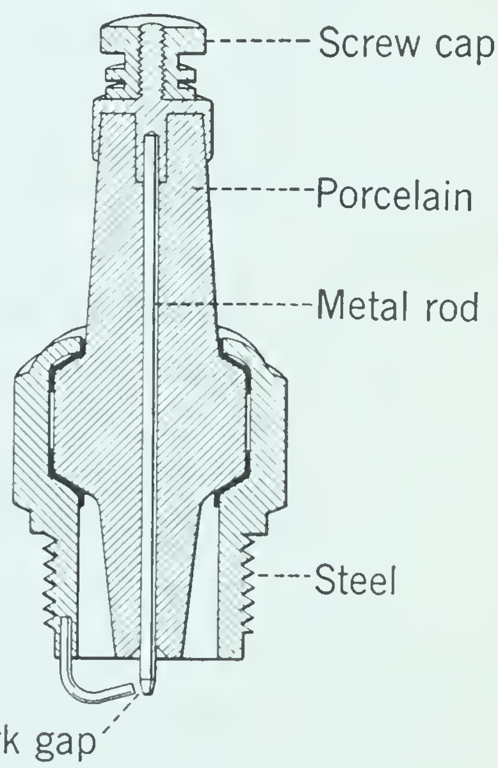


Fig. 14-22. The high voltage produces a discharge of electricity across the spark gap. The spark is hot enough to ignite the gases.

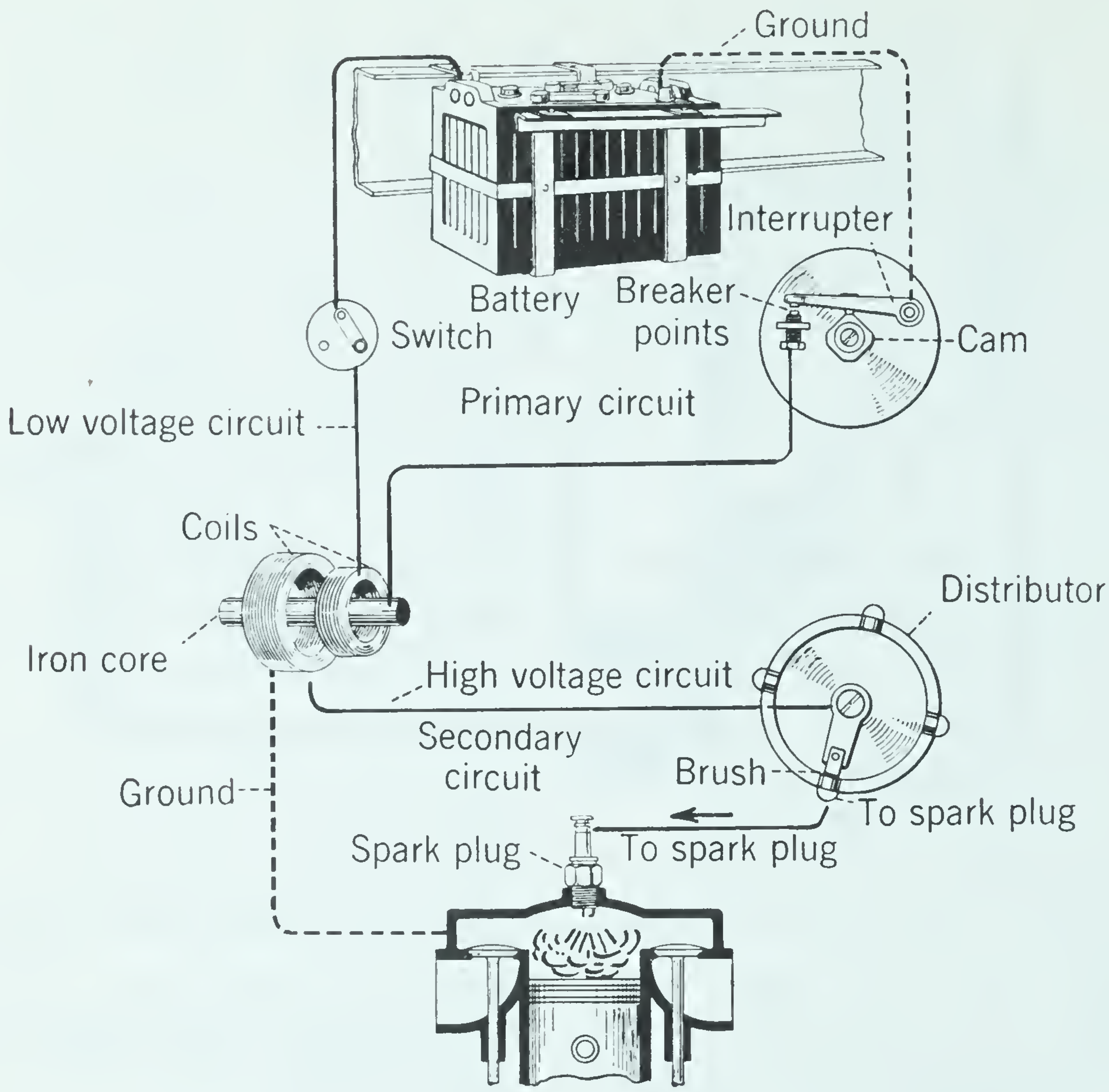


Fig. 14-23. The ignition system and distributor produce a spark to explode the gases in the cylinder at the proper time.

how to produce an electric current with another current. The storage battery in a car produces low voltage. Because it is necessary to have high voltage to produce a strong spark, a current is sent through the primary circuit of an induction coil.

An *interrupter* breaks and closes the circuit. Whenever there is a change in the strength of the current in the primary coil, an induced current of higher voltage is set up in the secondary coil. This is because there are a greater number of turns on the secondary coil. The *distributor* causes the secondary coil to discharge through each spark plug at the right time. Study the diagram in Fig. 14-23 and explain how the spark is produced by the spark plug.

The cylinders of a gas engine are cooled to prevent them from becoming overheated. The temperature of the exploding gas in a cylinder is approximately 2,300° F. Such a high temperature would soon ruin the engine. The gas would be ignited as rapidly as it entered the cylinder and explosions would be produced at the wrong time. This high temperature would also make it difficult to lubricate the engine because the oils would burn.

Therefore, water is pumped around the cylinders to absorb the heat from them. This water is then cooled as it circulates through the air-cooled radiator. How is the air drawn through the

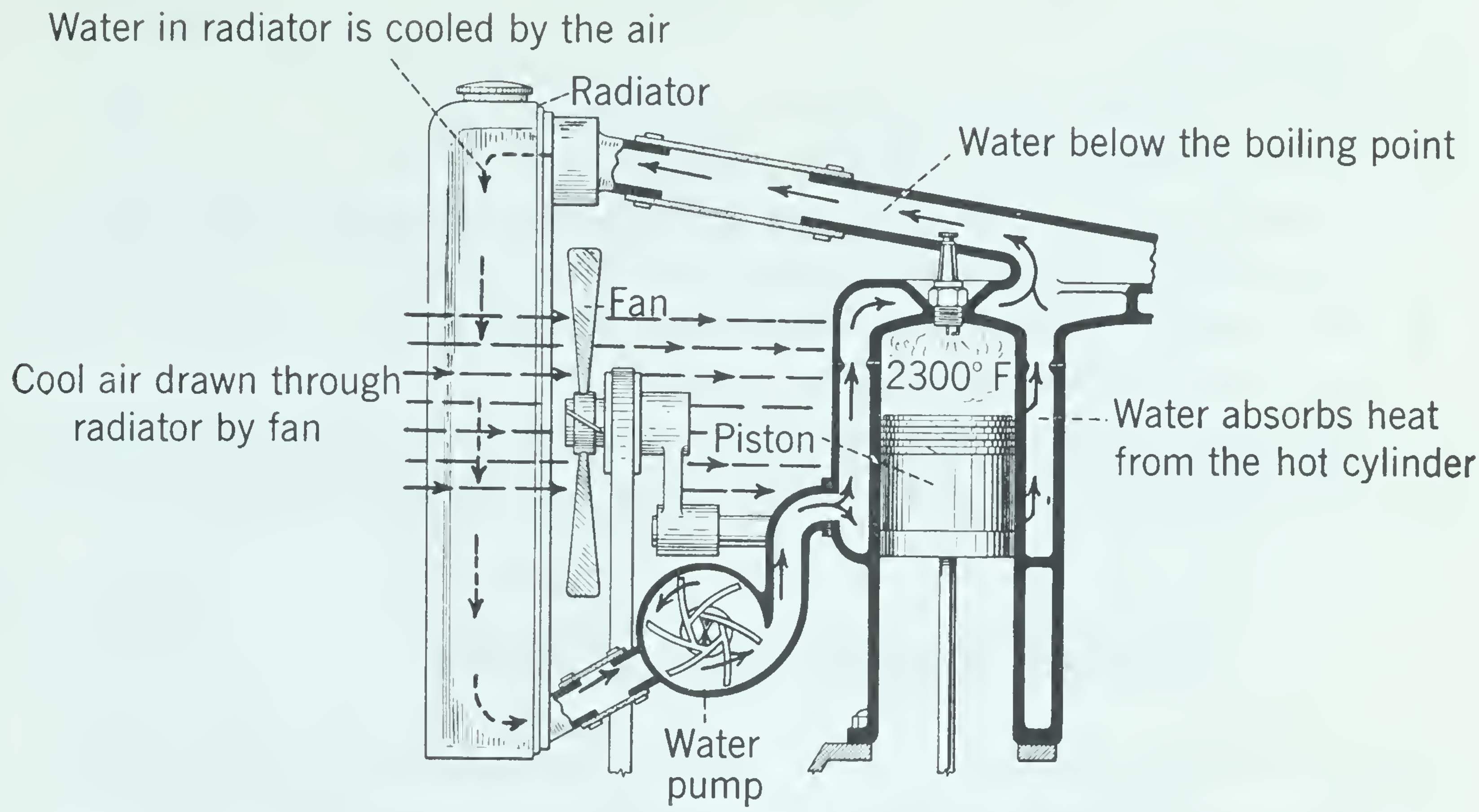


Fig. 14-24. The gas engine needs a cooling system to prevent the cylinders from becoming overheated. What might happen if the radiator became dry?

radiator? Some engines, especially airplane engines, are cooled by air alone.

There are other important types of internal combustion engines in use today. All rocket and jet engines are of this type. The Diesel engine is similar to the gas engine in construction. However, it burns oil as its fuel. The oil is injected into the cylinder and ignited by the high heat of compression within the cylinder. Thus it does not need spark plugs or a carburetor.

REVIEW QUESTIONS

1. In what part of the gas engine are air and gasoline mixed? **2.** What is meant by a "rich mixture"? **3.** What does a carburetor do? **4.** What are the four strokes in the common gas engine? What action occurs in each stroke? **5.** How is the electric spark produced? **6.** Why does a gas engine need to be cooled? **7.** What are some of the scientific principles which the automobile illustrates? **8.** In what ways are gas and steam engines alike? Unlike?

QUESTIONS FOR REVIEW AND DISCUSSION

1. In what two ways can metals be extracted from their ores?
2. How is pig iron converted into steel?
3. How is solder made? Name two uses of solder.

4. How is power obtained in a steam engine? How is this power changed into circular motion?
5. Why are flywheels used on steam and gas engines?
6. How are gasoline and air mixed in a carburetor?
7. Why does gasoline vapor mixed with air explode in a gas engine whereas gasoline burns quietly in an open container?
8. What do we mean by the term "adjusting the carburetor"?
9. How is power developed in the gas engine?
10. Why does a four-cylinder engine produce more even power than one-cylinder?
11. Why is it necessary to have a cooling system for a gasoline engine?

SPECIAL REPORTS AND PROBLEMS

1. Make a Bunsen burner.
2. Demonstrate how steam can be produced under pressure.
3. Demonstrate how an induction coil can be used to produce a spark.
4. Show how compressed air can be used to run a steam engine.
5. Report on the history of the automobile, airplane, and steam engine.
6. Demonstrate a model airplane gas engine.
7. Report on the different types of airplane engines.
8. Report on the Diesel engine.

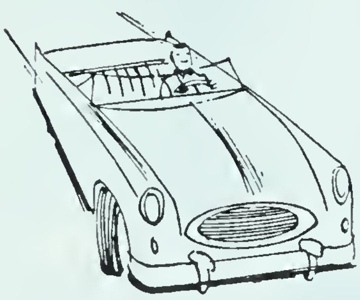
TESTING THE PURPOSES OF THIS UNIT

1. Define or give the meaning of each of the following words or terms: ore, alloy, carburetor, mineral, reduction, crucible, eccentric, cast iron, steel, roasting of an ore, engine, industry, wrought iron, welding, converter, steam pressure, blast furnace, natural resources, pig iron, internal combustion engine, gas engine.
2. Through what stages has man passed in his development of metals?
3. What effect do ores, fuels, and water-power have on the location of industries?
4. Explain why so many of the cities on the Great Lakes have important metal industries. Where do they get their metals, fuels, and power?
5. How have metals helped in the development of transportation and industry?
6. Starting with the first steam engine, what new principles of science have been applied in the gradual improvement and development of the modern engine, including the railroad locomotive?
7. How has the Bunsen burner helped in the development of the gas engine?
8. What types of engines are used in airplanes?
9. What further improvements are possible in the development of steam and gas engines for power and transportation?

The old

EARLIEST MAN USED IMPLEMENTS OF WOOD AND STONE. When man discovered metals, he was able to make a greater variety of tools and weapons. As more metals were separated from their ores, greater progress was made in the development of machines. The use of iron and steel made possible the industrial revolution of the 19th Century. At the same time, steam engines came into use in railroads and ships.

The new



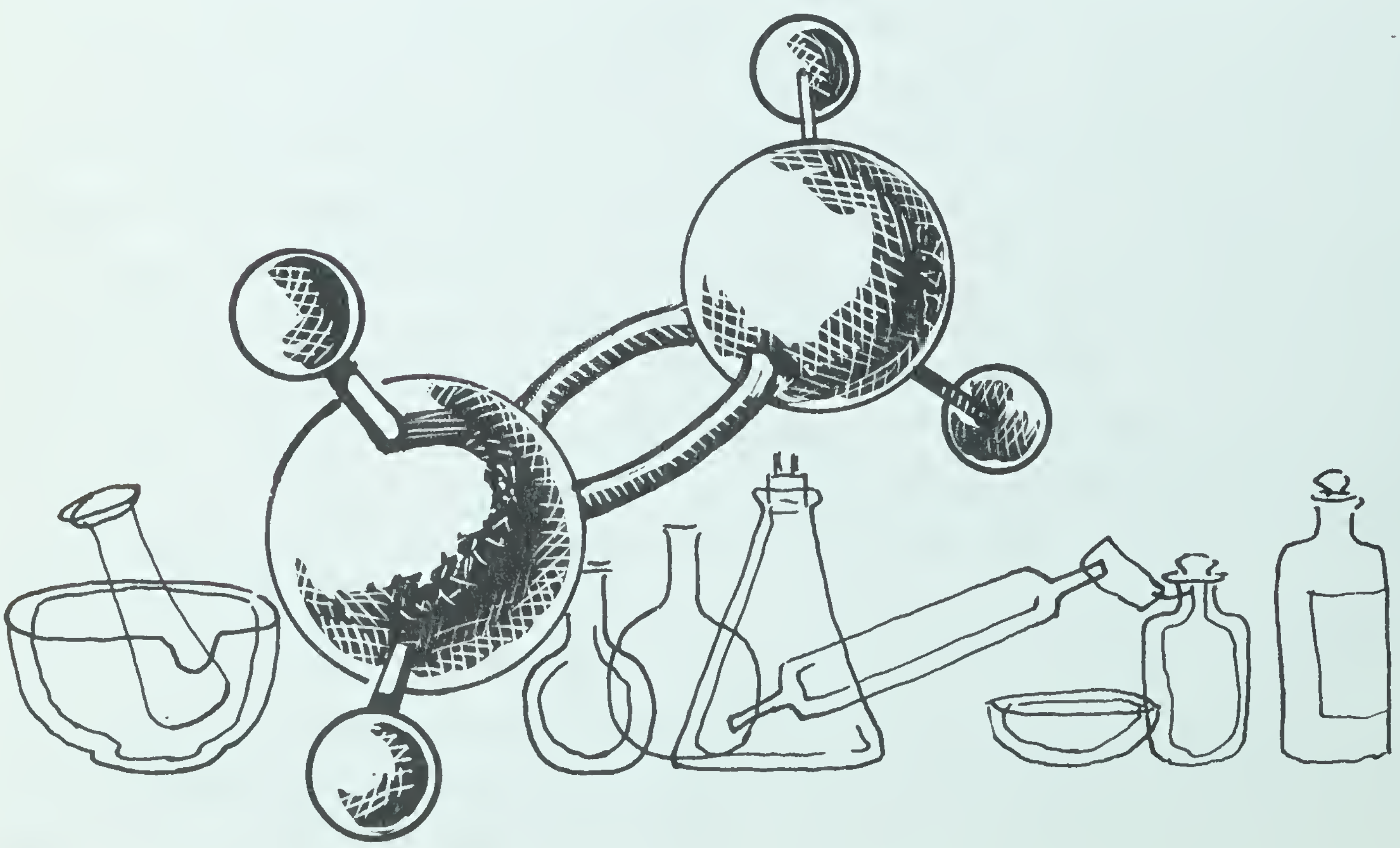
TODAY WE STILL USE IRON AND STEEL. HOWEVER, WE HAVE also developed new light-weight metals, such as aluminum and magnesium. Plastic materials, too, are now replacing metals in the manufacture of many of our common objects.

In the field of machinery, internal combustion engines have, in many cases, replaced the steam engine. In factories electric motors now turn most of the machines used for the production of consumer goods. Modern machines make it easier to mine coal and the ores of metals. Newer types of blast furnaces and electric furnaces mean increased production of important metals.

In the future new alloys and synthetic materials may replace the metals we use today. Solar engines and atomic reactors could, in years to come, furnish the power now obtained from the burning of coal and oil.

Ancient Egyptians
Learned to Blow Glass

Priestley Used Mice
in Experimenting
with Oxygen



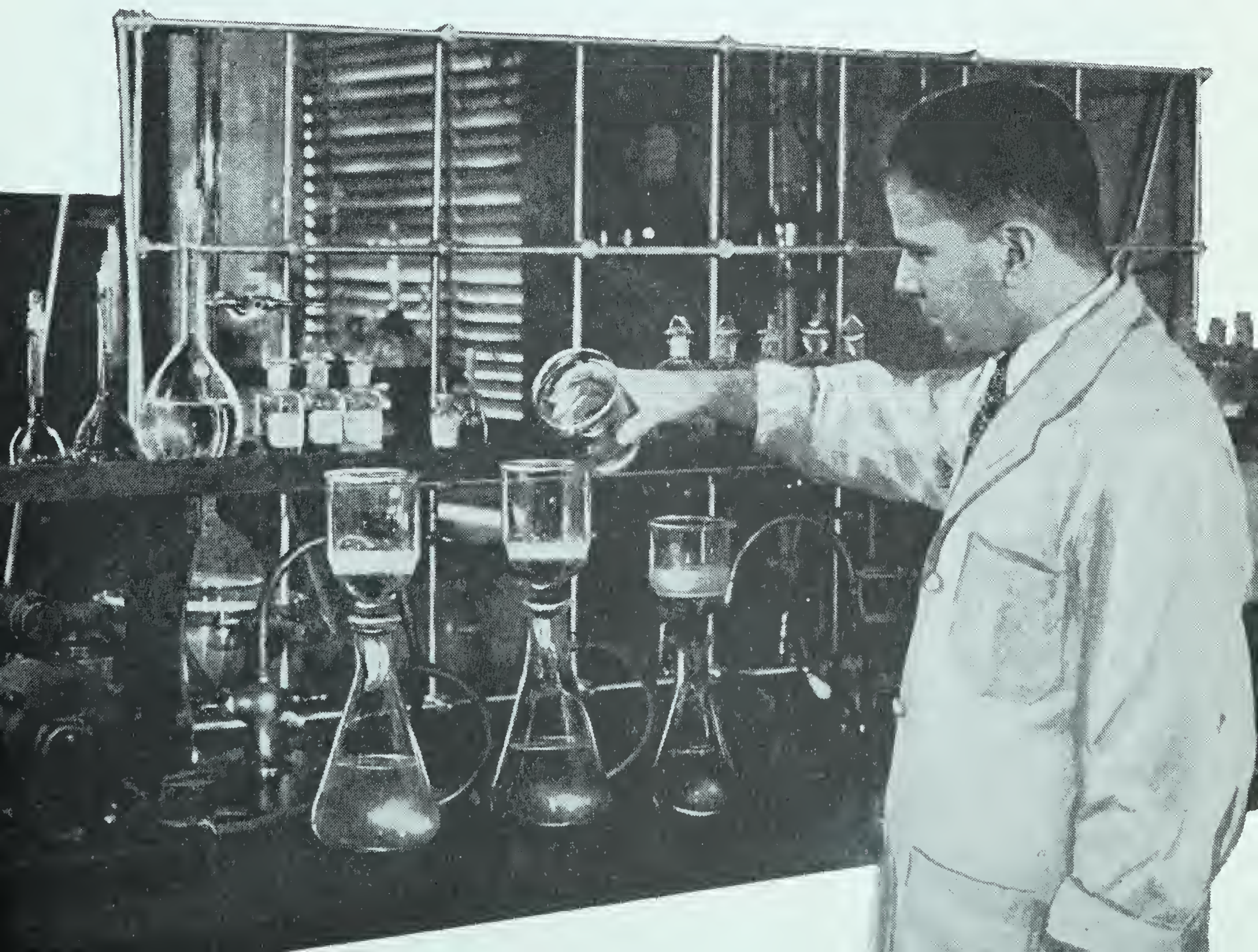
UNIT 15

How has man learned the nature and uses of chemicals?

DISCOVERY AND PROGRESS

SCIENTISTS have found objects buried in the earth by ancient man that seem to prove he knew something about chemistry. In the Egyptian tombs they have found drawings showing men making glass. Thus, man knew how to make glass vases at least 2,000 years before the birth of Christ.

Later, as men began to write books, they wrote down the directions for making wine, vinegar, pottery, dyes, and other things. The making of all these involves chemistry. However, the



science of chemistry had not developed into the orderly process we know today. All the directions were general, and lacked many of the details for making these things. Few of the people at that time could read, anyway. One big difference between that period and ours is that ancient man did not try to understand *why* these chemical operations took place.

Some of the Greeks who lived four or five centuries before the Christian era had ideas that matter was made up of elements. During this period, also, some of them proposed that matter must be present in small particles which we now call *atoms.*

Then came a period of a thousand years in which little progress in chemistry was made. But during the Renaissance in the 15th Century there was a reawakening of interest in learning. Real progress was made in chemistry as well as in other fields. Yet this progress was slow because scientists working alone had no way of communicating with each other easily.

We often say that modern chemistry began with the discovery of oxygen. Joseph Priestley, an English scientist, first made oxygen and published his discovery in 1774. He did not realize the importance of this gas, however. Later, a French scientist, Antoine Lavoisier (la-*vwah*-zee-ay), repeated Priestley's experiments and learned new things about oxygen. Lavoisier was clever enough to realize the importance of oxygen in such processes as breathing and burning. Once man learned what took place when things burned, progress was rapid. Lavoisier used a balance, also, to weigh the raw materials he used and the products he got. This helped man to understand more about the laws of chemistry.

Soon there was more interest in chemistry among men of learning. Some were great experimenters, such as Humphry Davy, an English scientist, and Jons Berzelius (ber-*zee*-lee-us), a Swedish chemist. Others were great thinkers who gave us some of the important statements that we now call the laws of science. John Dalton, an English schoolteacher, gave us the atomic theory in a more modern form, while Avogadro (ah-voh-*gah*-dro), an Italian chemist, proposed a statement that has helped us to learn more about the molecules that compose substances.

Progress has not stopped by any means. It is going on every day. New discoveries are reported in the newspapers every week as more and more people study chemistry and unravel its mysteries. One of the greatest achievements that man has made in all time occurred during the 1940's when he found out how to split the atom. True, we used it to make atom bombs that created great destruction, but we are also finding ways to use this powerful source of energy for peacetime uses as well. Thus man has progressed in the field of chemistry from the meager beginnings of 4,000 years ago to the scientific marvels of our present age.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How do we recognize and classify substances? **2.** What three kinds of particles make up the atoms of all elements? **3.** How is chemical shorthand used to represent atoms, molecules and chemical changes? **4.** How do we write chemical formulas? **5.** What are some of the properties of acids? **6.** Why are strong bases called caustic substances? **7.** What is a salt to a chemist? Why can we not live without salts? **8.** What are the three materials usually present in baking powders? **9.** Why are plastics so popular?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

acid . . . . a compound containing hydrogen whose water solution tastes sour and changes blue litmus paper to red.

atomic weight . . . the weight of a given atom compared with the weight of an oxygen atom considered as 16.

base . . . . a compound of a metal and one or more OH radicals whose water solution tastes bitter and changes red litmus paper to blue.

combining number the number of hydrogen atoms that join with one atom of another element.

electron . . . . one of the particles of an atom having a unit charge of negative electricity.

equation . . . . a shorthand method of showing how atoms rearrange themselves during a chemical change.

formula . . . . a combination of symbols representing an element or a compound and showing its composition.

neutron . . . . one of the particles of an atom having no electrical charge.

proton . . . . one of the particles of an atom having a unit charge of positive electricity.

radical . . . . a group of elements that acts as a unit in a chemical change.

salt . . . . a compound made by the reaction between an acid and a base.

A What are the kinds of substances the chemist uses?

A substance is a material of uniform composition. Water, salt, iron, sugar and oxygen are substances. If pure, each of these always has the same make-up or composition. A great many other substances are all about us. However, in nature, a particular substance is usually found mixed with other substances. Salt is found with other substances in sea water or salt deposits. Oxygen is only one of the substances found in air. Ditch water is not the same along every roadway.

Elements are the simplest of all substances. Everything in this world, whether living or non-living, is composed of chemical elements. You have seen copper wire, iron posts, lead pipes, gold and silver jewelry. These materials have a shinyness about them which is called luster, though it may be necessary to scrape or polish them before the luster is noticeable. All of them conduct or carry heat and electricity very well. They are all ***metals***. There

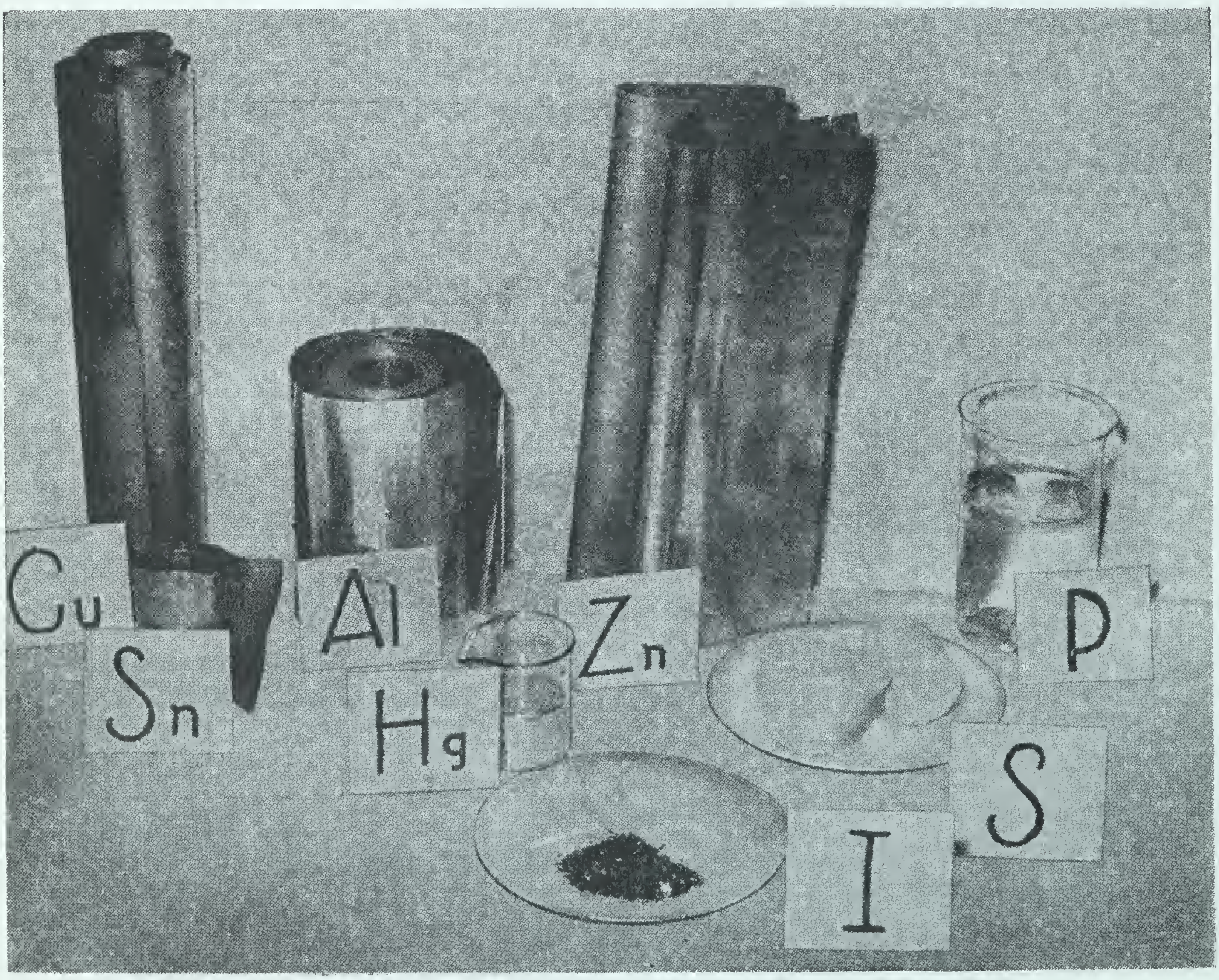


Fig. 15-1. Which of these elements are metals? Which are nonmetals?

are many other metals besides these.

In an art class you may have sketched with a carbon stick or pencil. Your teacher will show you lumps of sulfur and crystals of iodine. He will let you see a stick of phosphorus immersed in a bottle of water. (Phosphorus burns so easily that we keep it under water to prevent an accidental fire.) All four of these—carbon, sulfur, iodine, and phosphorus—are nonmetals. ***Nonmetals*** usually lack the luster of metals and conduct heat or electricity very poorly.

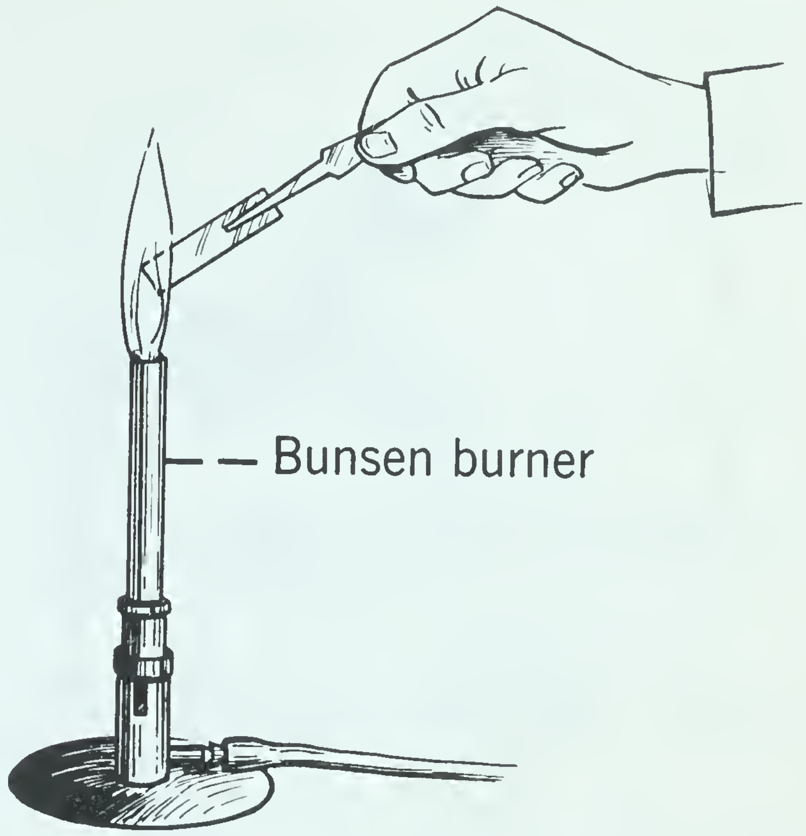


Fig. 15-2. When copper is heated to a high temperature, it forms a black coating.

PUPIL ACTIVITY

Examine samples of different metals for color, hardness, luster, elasticity, etc. Pieces of sheet zinc, copper, lead, iron, and tin are suitable. A bottle of mercury is interesting as a liquid element. Note that the metals have a metallic luster.

Examine a few nonmetals such as a block of carbon, a lump of sulfur, a few crystals of iodine, and a stick of phosphorus. (CAUTION: *do not remove the phosphorus from the bottle, or touch it with your fingers.*)

Both the metals and the nonmetals you saw above are substances which are called elements. An *element* is a simple substance that cannot be broken up into anything simpler by any ordinary means. No matter what you do to a lump of sulfur or a piece of iron, you cannot break up either of these into anything simpler. You can separate air, wood, water, and many other things into two or more simpler substances because they are not elements.

There are more than 100 elements known to chemists. Before 1939 there were 92 elements known to chemists. During and since World War II scientists working with uranium and similar elements "built up" other elements. One of these was plutonium which is used in certain atomic explosions. Further nuclear research may produce other elements.

All the elements are alike in one respect: they are all simple substances containing nothing but that particular element. Yet, they differ in the qualities by which we recognize them. Some are hard, others soft; some have a luster, others are dull; some are solids, others are gases; and three are liquids at ordinary temperatures. Some unite readily with other elements, while others stay just as they are and will not unite with any other substance.

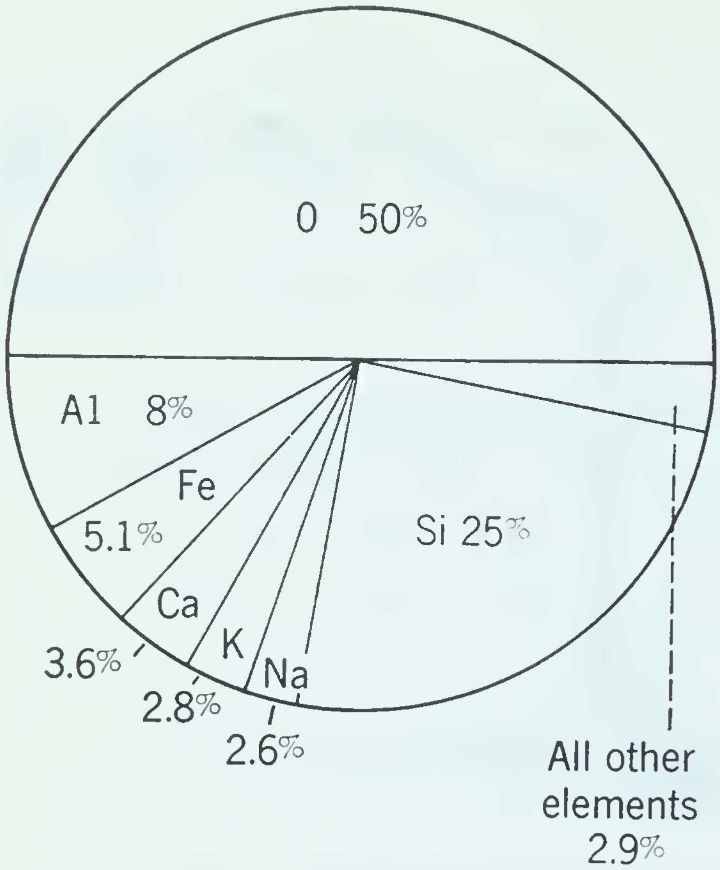


Fig. 15-3. The diagram above shows the relative percentage of certain chemical elements that are usually found in the earth's crust.

DEMONSTRATION

Using forceps, hold a strip of lead in a burner flame as in Fig. 15-2. Note how easily it melts. Try the same test with a strip of copper, tin, and zinc. Do some metals melt more easily than others?

Rub some strips of copper with sandpaper until they are bright. Then, hold one of them in the flame until it is red-hot. Let it cool and then compare it with a strip that has not been heated. What change do you notice in copper when it is heated to a high temperature?

Using forceps, hold a piece of magnesium ribbon in the flame until it ignites. Note what a bright light it produces. Examine the material that is left and see how different it is from the magnesium metal.

Ignite a piece of sulfur in a burning

SOME COMMON NATURAL ELEMENTS

Aluminum	Gold	Oxygen
Antimony	Hydrogen	Phosphorus
Arsenic	Iodine	Potassium
Barium	Iron	Silicon
Bismuth	Lead	Silver
Bromine	Magnesium	Sodium
Calcium	Manganese	Sulfur
Carbon	Mercury	Tin
Chlorine	Nickel	Tungsten
Copper	Nitrogen	Zinc

THE MAN-MADE ELEMENTS

Neptunium	Curium	Mendelevium
Plutonium	Berkelium	Einsteinium
Americium	Californium	Fermium

spoon and note the color of the flame. Cautiously smell the gas that comes off the burning sulfur. Make a list of the characteristics of each of the elements which you have learned in this demonstration.

A compound is formed when two or more elements unite chemically. When two or more elements join to form a new substance, we call the product a *compound*. Let us try it with the mixture of iron and sulfur.

Fig. 15-4. This is a mixture of iron filings and powdered sulfur. The magnet attracts only the iron filings.

DEMONSTRATION

Weigh out 5 grams of powdered iron and 2.85 grams of powdered sulfur and mix them on a piece of paper. Put a small amount of this mixture into water and shake well. Let it stand for a minute. Do the iron and sulfur separate? Put a magnet near a small amount of this mixture, as shown in Fig. 15-4. Result? Now, slide the mixture into a large test tube. Use a clamp to hold the test tube. Heat the tube very gently at the bottom at first, otherwise it will break. Then, gradually heat more strongly until the mixture gets red-hot at the bottom of the tube. Stop heating the tube and note what happens to the mixture.

Heat and light are often set free when a compound forms. When the tube is cool, break it and examine the black product. Try the effect of a magnet on the product. Is it now a mixture of iron and sulfur or a compound of the two elements?

When the iron and sulfur combined, a chemical change took place. A new compound, *iron sulfide*, was formed. In *chemical changes* a new substance is always formed with properties different from those which the elements originally had.

In a chemical change there is always a change in temperature. Heat is either given off or taken on. A large amount of energy was given off when the sulfur and iron combined with each other. Also, the weight of the compound is equal to the weight of the elements combining to form it. Five grams of iron plus 2.85 grams of sulfur give 7.85 grams of iron sulfide.

A pure compound always has the same composition. When you made the compound from iron and sulfur, you weighed out the elements and mixed them in *definite proportions*. A ***compound*** is a substance composed of chemically united elements in definite proportions by weight. That is one of the facts about compounds—they always have the same elements united in the same proportions by weight. If you take cane sugar apart, or as the chemist says, analyze it, you find that it always has exactly the same percentage of carbon, hydrogen, and oxygen by weight.

Two or more substances can form a mixture. When you add some powdered iron to powdered sulfur and stir

them together, you have a *mixture*. Each of these elements is present in the pile you make in this way. Just stirring the iron and sulfur together does not cause them to join. They simply form a pile of material in which the particles of iron and sulfur are side by side. A mixture consists of intermingled substances without regular composition. Soil is one mixture found in nature. You may have made mud pies out of clay soil which is a fine-grained mixture. Have you noticed that few plants grow in soil that is chiefly sand or gravel?

We recognize substances by their properties. Just as a boy knows his dog by its color, bark, and general appearance, so the element, copper, may be recognized by its properties. You know that copper is reddish in color, that it is heavy, and that you can bend it without breaking it. When copper is heated you find that it does not melt easily. These are some of the properties of copper. The white solid we call table sugar tastes sweet and dissolves readily in water. Perhaps, when making candy, you have overheated this compound until a charred mass, chiefly carbon, formed. These are some of the characteristics or qualities of table sugar.

In chemistry, properties are divided into two classes: (1) *physical properties*; and (2) *chemical properties*. ***Physical properties*** include color, odor, taste, weight, and hardness. ***Chemical properties*** describe how the substance behaves in reaction with other substances or what happens to it when it is treated with heat, light, or electricity.

The properties of a substance determine what uses we make of it. We like to use sheets of copper around the chimney on a roof because it will last a long time. Iron would rust away and the roof would soon leak. Since copper does not rust like iron, that property makes it suitable for many purposes. Yet, iron in the form of steel has great hardness and strength. That is why we prefer iron in the form of steel to the softer metal, copper, for making

IRON + SULFUR ⟶ IRON SULFIDE

Fig. 15-5. When iron and sulfur are combined by chemical means, a new compound, iron sulfide, is formed.

knives, chisels, and saws, as well as for railroad rails and steel beams for bridges. As you continue your work in science, you will find that it is important to learn the properties of new substances you use.

REVIEW QUESTIONS

1. What is an element? **2.** How many elements are there? **3.** How do metallic elements differ from nonmetallic elements? **4.** What is the luster of copper? gold? iron? **5.** What happens when two or more elements form a compound? **6.** How does a mixture differ from a compound? **7.** How do you distinguish between a physical property and a chemical property?

B What kinds of particles make up substances?

Substances are made up of small particles called molecules. If you spread out a few grains of sugar on a piece of black paper, you see particles that have the same shape. Each little grain of sugar is made up of a large number of still smaller particles called *molecules*. We cannot see the individual molecules because they are too small. Even in one grain of sugar there are many, many thousands of them. As you learned in Unit 2, a molecule is the smallest particle of a substance that exists and has the properties of that substance.

PUPIL ACTIVITY

Sprinkle a few crystals of sugar on a piece of black paper. Use a magnifying glass to examine the crystals. What is their shape? If you could cut one of these crystals into two parts, would each fragment still be sugar? What do you call the smallest quantity of sugar that has the properties of this substance?

Molecules of all substances consist of still smaller particles called atoms. An *atom* is the smallest part of an element that can exist in a molecule.

Even atoms are made up of still smaller particles. A grain of sugar seems quite small. A molecule of sugar is many times smaller. And the atoms that make up the molecules of sugar are still smaller. Yet, we now know that atoms are made up of even smaller particles.

Each atom of an element, such as oxygen, for example, is made up of three kinds of particles. These particles are: (1) *protons* (*proh*-tonz); (2) *electrons* (ee-*leck*-tronz); and (3) *neutrons* (*new*-tronz). In the same way, we find that the atoms of other elements have the same three kinds of particles. In fact the difference between an atom of iron and an atom of gold is in the number of these particles which each contains.

Protons and electrons are parts of the atom which have electric charges. The *proton* has a single charge of positive electricity. The *electron* has a single charge of negative electricity. We do not fully understand just what electricity is, although we can do many things with it. But we do know that atoms are made up of particles containing positive and negative electricity. The *neutron* has no electric charge.

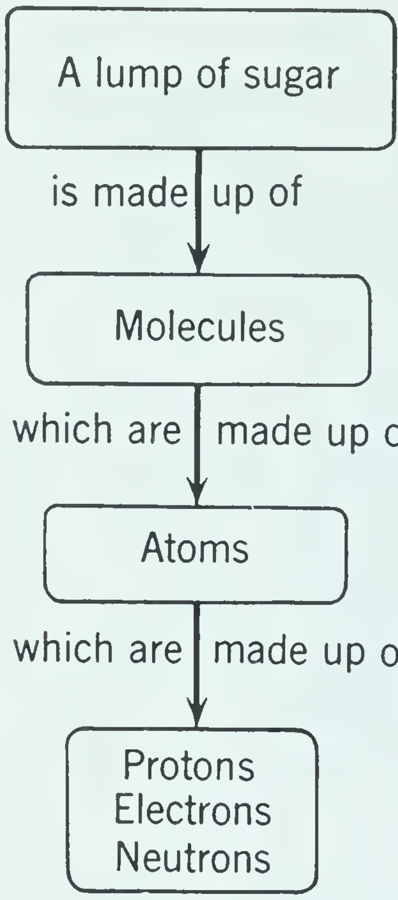


Fig. 15-6. A small lump of sugar is made up of many thousands of molecules that are made up of still smaller particles.

In some ways, it behaves as though it is an electron and a proton combined.

The hydrogen atom is the simplest kind of atom. It contains only one proton and one electron. It has no neutrons.

The protons and neutrons are gathered in a cluster at the center of the atom. Together they form what we call the *nucleus* of the atom. The electrons are spaced around the nucleus in rather definite shells or orbits. They do not revolve in the same manner as planets revolve around the sun. It might be better to compare them to a swarm of bees about a hive, except that they are spaced in a more orderly arrangement, and usually stay within their own shells.

The simplest atom, that of hydrogen, has one proton. The next simplest has 2 protons, the next 3, and the next 4 protons, and so on. The number of protons in the nucleus of an atom determines what element it is. Oxygen atoms have 8 protons, sulfur atoms have 16, calcium atoms have 20, silver atoms have 47, and the atoms of gold have 79 protons. The most complex atoms found in nature are those of uranium. They have 92 protons, 92 electrons, and a still larger number of neutrons.

You need not memorize the number of protons, electrons, and neutrons in the atoms of different elements. What you should understand is that these same three kinds of particles make up the different kinds of atoms. All of the elements from those with 1 up to those with 92 protons have been separated. In addition, chemists have been able to add particles to some of the most complex atoms to make such new elements as *plutonium* (plew-*tone*-ee-um) and *californium*, and others listed in the table on page 422.

The use of nuclear energy developed from the discovery that certain atoms can be split. Scientists have found two

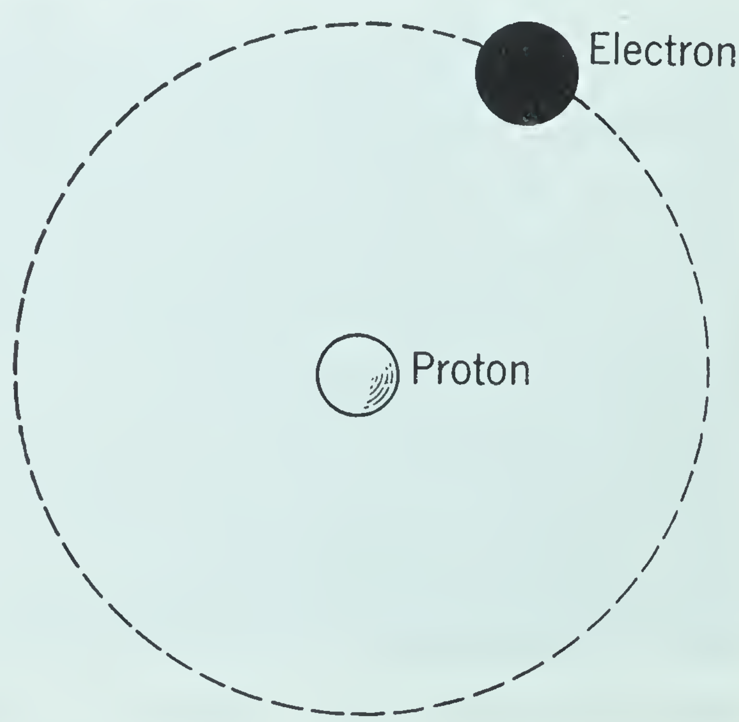


Fig. 15-7. The simplest atom, hydrogen, contains only one proton and one electron.

ways of splitting atoms. One is to use an instrument known as ***particle accelerator***; the most common type of particle accelerator is known as a ***cyclotron*** (*sy*-kloh-tron). The particle used in these machines must possess an electrical charge. Cyclotrons are used for experimental work, but the number of atoms that can be split is extremely small. The energy released by the atoms split in this way is much less than the amount of energy needed to run the cyclotron.

The second method is called ***fission*** (*fish*-zhun) by neutron bombardment. *Fission* is another word for cutting or splitting. It is this method which is used in the actual practice for obtaining large quantities of nuclear energy. You will recall that almost all atoms contain neutrons. When an atom splits, it gives off, in addition to the two new atoms, two or three neutrons. These in turn bombard other atoms. Of course,

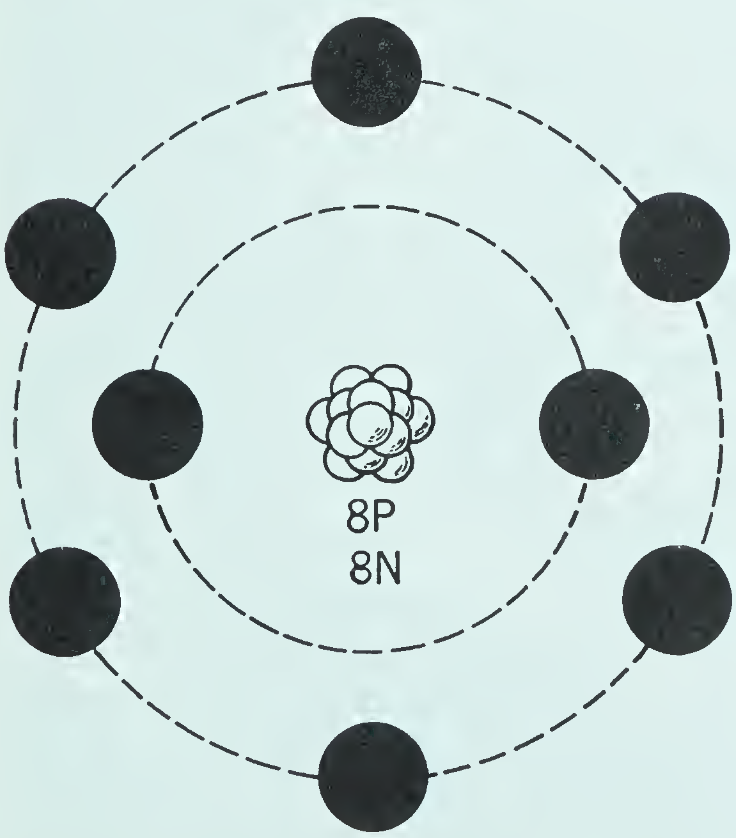


Fig. 15-8. The oxygen atom contains 8 protons and 8 neutrons. How many electrons does it contain?

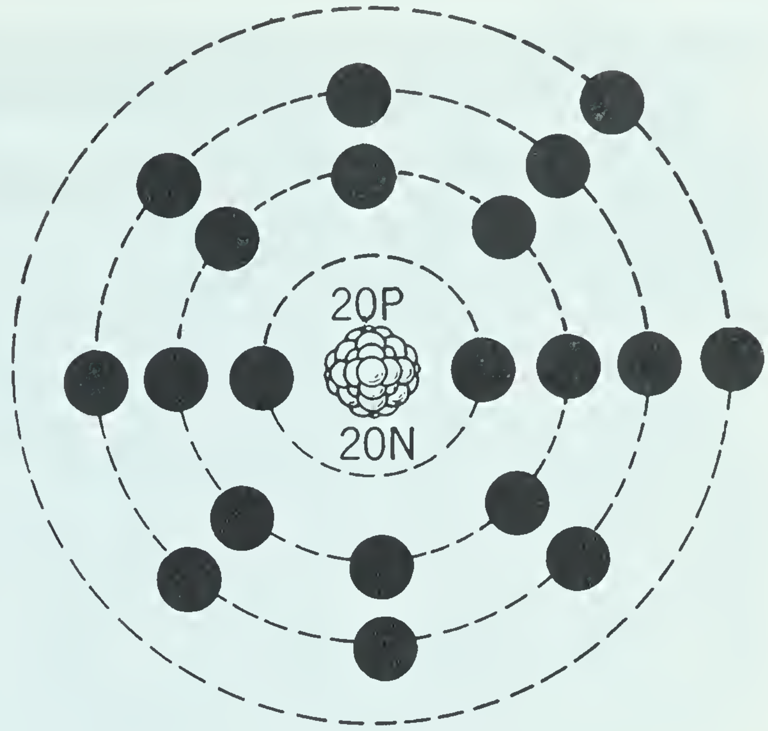


Fig. 15-9. The calcium atom, a more complex atom than the oxygen atom, contains 20 protons and 20 neutrons. How many electrons does it contain?

not all atoms split when they are bombarded by neutrons. As a matter of fact, very few kinds of atoms are capable of fissioning when hit by a neutron. One of these is found in the element uranium, but even uranium contains only a few atoms that can fission. Scientists refer to these fissionable atoms in uranium as U-235. The rest of the atoms that make up the element uranium are known as U-238. A very interesting thing happens when these U-238 atoms are bombarded with neutrons. Instead of fissioning, they eventually change into the element plutonium. This element fissions just as U-235 does when bombarded with neutrons.

To bring about the change of U-238 to plutonium, scientists build what is called an *atomic pile*. A pile is usually made of three substances: (1) *uranium*; (2) *graphite* (a form of carbon); and (3) *metallic rods* to control

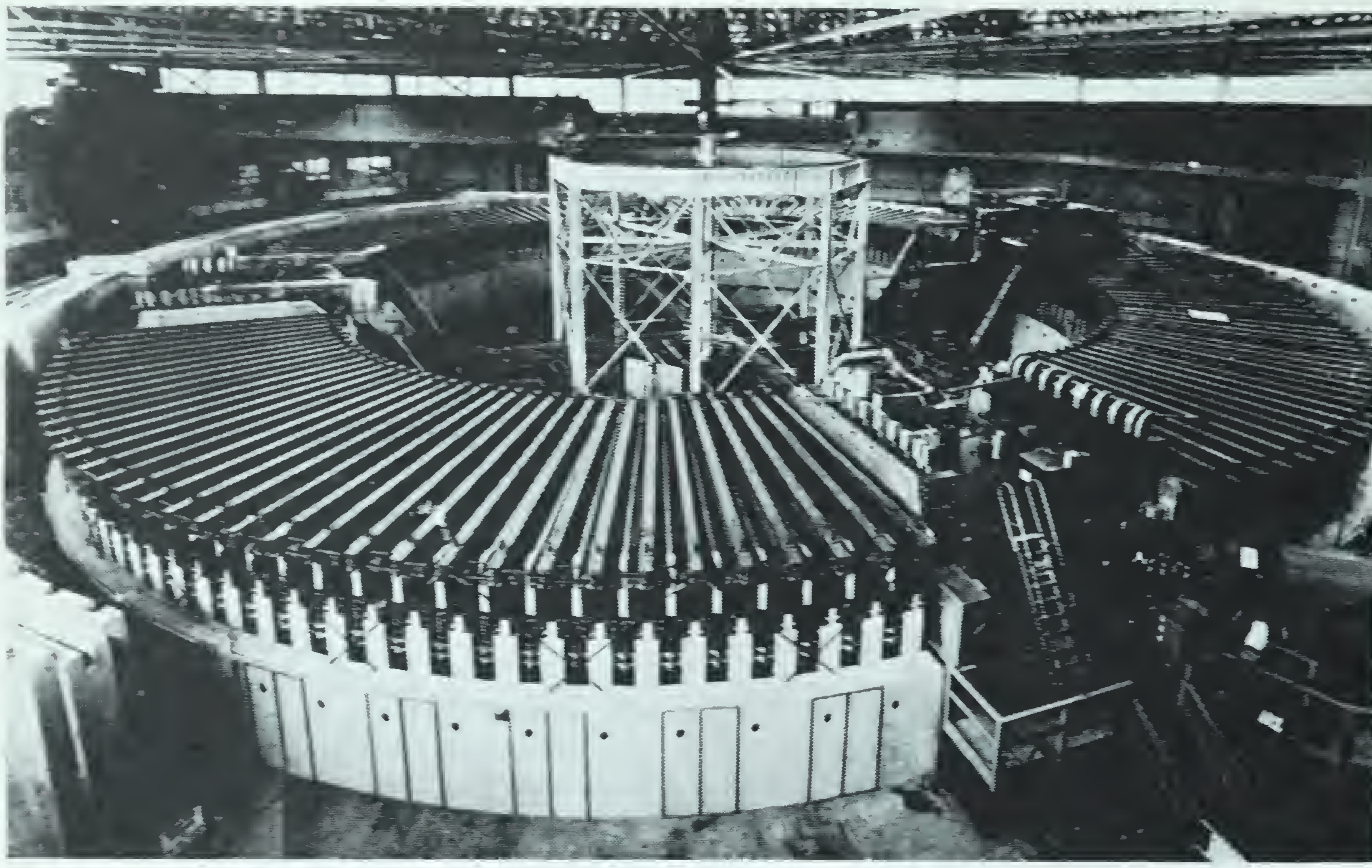


Fig. 15-10. This cyclotron, which is at the University of California, is used to bombard chemical elements with charged atomic particles.

the speed of the reaction. Both the splitting of atoms and the formation of plutonium by neutron bombardment are called chain reactions. A *chain reaction* is one which is continuously repeated because something needed to cause the reaction is given off by the reaction itself. What is given off here that causes the chain reaction?

It is this fissioning and the chain reaction which causes tremendous amounts of energy to be given off, such as the explosion of the atomic bomb.

The opposite of fission is fusion. That is, instead of a "cutting" process, the nuclei (more than one nucleus) of very light atoms combine to form larger atoms, and in the process also give off energy. The so-called hydrogen bomb gives off great amounts of energy by the combining of a type of hydrogen atom into a heavier atom, probably helium. This same process goes on in the sun and accounts for the great amount of energy it gives off.

The use of atomic energy in medicine, industry, and transportation is an important field of investigation today. Some elements are *radioactive*; that is, they break down into simpler elements. This process is accompanied by the release of dangerous radiations. Safety devices must be found for workers who come into contact with these elements to protect them from the deadly rays which some of these radioactive elements give off.

Although radioactive elements are used in the atomic and hydrogen

bombs, they do have other uses. Their radiations are employed in the treatment and cure of cancer. Research scientists use them as "tracers" to learn how plants and animals use various elements. Atomic power is coming into wider use. The United States Navy now has two submarines powered with atomic engines. In a few places, atomic reactors are now being used to generate electricity for home and industry.

We must hope that international agreements will lead to the control of atomic energy in warfare. It is conceivable that unwise use of this great force could destroy all life on the earth. On the other hand, the use of atomic energy for peaceful purposes could result in untold benefits to humanity.

REVIEW QUESTIONS

1. What do we call the particles of sugar that make up the individual grains? **2.** What still smaller particles do the molecules of sugar contain? **3.** What are the three kinds of particles that make up atoms? **4.** How are these particles arranged in an atom? **5.** What is the simplest atom? The most complex natural atom? **6.** What parts make up the nucleus of the atom? **7.** What electrical charge does the electron have? **8.** Name two elements that can be used in producing atomic energy. **9.** What is a radioactive element? Name a few. **10.** What are some of the possible peacetime uses of atomic energy? **11.** How are new elements made?

Fig. 15-11. These volunteers are breathing into special respiratory helmets to determine the amount of radium deposits in their bodies. The men who are subjects for the experiment were given drinking water with a heavy concentration of radium.

C What shorthand signs are used to represent atoms and molecules?

The actual weights of the atoms of the elements are very small indeed. One atom of oxygen weighs 0.000,000,000,000,000,000,000,026,57 grams. You can see that this is so small that it has no practical value. To overcome this difficulty chemists compare the weights of the elements with each other, using one element as a standard. These relative atomic weights, as they are sometimes called, have a definite relationship to the actual atomic weights but they are much easier to use.

An atom of oxygen, the most abundant element, was selected as the standard. It has been found convenient to give the oxygen atom a weight of 16. Since the sulfur atom is twice as heavy as the oxygen atom the atomic weight of sulfur is 32. On the same basis the atomic weight of hydrogen, the lightest element, is 1, and the atomic weight of chlorine is 35.5. In the table on page 432 you will find approximate atomic weights of the more common elements. Chemistry text-books give more accurate atomic weights.

Each element is given a symbol of one or two letters of our alphabet. It is easier to use the letter O when we want to write *oxygen* than it is to write the whole word, and the letter H for *hydrogen* is also easier to write than the whole word. In the same way we use C for *carbon*, N for *nitrogen*, and I for *iodine*.

When we write the symbol for an element, the symbol begins with a capital letter. If there is a second letter, it is always a small letter. The table on page 432 lists some of the more common elements with their symbols. Perhaps you wonder why *silver* has the symbol Ag, and *lead* has the symbol Pb. The symbols of some of the elements are taken from their Latin names. The Latin word for silver is "argentum" and for lead is "plumbum."

But chemical symbols are more than mere shorthand signs. One great advantage of such a system is that a symbol expresses so much in such a small space. A ***symbol*** represents (1) one atom of an element and also (2) one atomic weight of the element. The symbol O stands for one atom of oxygen and 16 units of atomic weight of oxygen. Na means not only one atom of sodium, but 23 units of weight of sodium. What is the full meaning of Zn?

A chemical formula tells us what elements make up a compound. Perhaps you have already seen a bottle in the laboratory with the formula H_2SO_4 on the label. You know that H stands for hydrogen, S for sulfur, and O for oxygen. Now, let us see what the chemical formula as a whole means.

A ***chemical formula*** (1) represents one molecule of an element or a compound, (2) tells us what elements are present, (3) tells us how many atoms of each element are in the molecule, and (4) represents the molecular or

formula weight. Thus the formula H_2SO_4 means that one molecule of sulfuric acid is composed of 2 atoms of hydrogen, 1 atom of sulfur and 4 atoms of oxygen and that its formula weight is $(2 \times 1) + 32 + (4 \times 16)$ or 98. Notice that the number of atoms of an element is written after the symbol, and slightly below the line. If there is only one atom of an element, you do not need to put a number down. The formula for water is H_2O and the formula for common salt is NaCl. Three molecules of water are written $3H_2O$, and 5NaCl represents 5 molecules of common salt. Sugar has the formula $C_{12}H_{22}O_{11}$. You should be able to explain the things this formula tells us. Chemists find formulas very useful because they tell at a glance what is in the compound. Also, they are easier to write than long, chemical names. A table that follows gives the names and formulas of a few common chemical compounds.

NAME	FORMULA
Water	H_2O
Table salt	NaCl
Carbon dioxide	CO_2
Sand	SiO_2
Cane sugar	$C_{12}H_{22}O_{11}$
Sulfuric acid	H_2SO_4
Lime (slaked)	$Ca(OH)_2$
Baking soda	$NaHCO_3$
Iron sulfide	FeS
Acetic acid	HC_2HO_2

Some elements, usually gases, have 2 atoms in the molecule. Thus, the formula for oxygen is O_2, and $4O_2$ stands for 4 molecules of oxygen. N_2 represents one molecule of nitrogen. Cl_2 and H_2 are also formulas. In the case of most elements, however, there is only one atom in the molecule. Fe is the formula for iron and represents one molecule of that element. Of course, Fe is also the symbol for iron. C, Zn, Pb, Ag, and Al are all formulas. 6Cu represents 6 molecules of copper.

Sometimes a group of elements acts as a unit. Just as players on a baseball team play as a unit in a game so certain groups of atoms act together and keep their identity in a chemical change. A group of elements acting as a whole in a chemical change is called a ***radical***. Such groups are sulfate ($-SO_4$), nitrate ($-NO_3$), ammonium (NH_4-) and many others. You will find a table of some common radicals in Part D. K_2SO_4 is potassium sulfate. If we have more than one radical in a molecule of a compound, a bracket, followed by a small number to tell us the number of times the radical is taken, is placed around the radical. Magnesium nitrate is written $Mg(NO_3)_2$. $(NH_4)_2CO_3$ is the formula for ammonium carbonate. What is the name of $Al(OH)_3$?

The chemical name of a compound containing 2 elements ends in ——ide. We name a compound of 2 elements by stating the name of the first element, and then, following this, most of the other element ending in —ide. Table salt has the formula NaCl and contains 2 elements, sodium and chlorine, so its chemical name is sodium chloride.

In a two-element compound the first part is usually a metal, hydrogen or the ammonium radical. Hydrogen oxide is the chemical name for water, H_2O. What is the name of ZnS? of NH_4I? What elements are in calcium carbide? In lead bromide?

The percentage composition of a substance can be calculated from its formula. Let us illustrate the method used. In a certain class there are 7 girls and 21 boys, giving a total of 28. The percentage of girls in the class is $\frac{7 \times 100}{28} = 25\%$ and the percentage of boys is $\frac{21 \times 100}{28} = 75\%$.

To find the percentage composition of water, H_2O, the formula weight is found first.

$$2H = 2 \times 1 = 2$$

$$O = 1 \times 16 = 16$$

$$18 = \text{formula weight.}$$

Percentage of hydrogen in water =

$$\frac{2 \times 100}{18} = 11.19\%$$

Percentage of oxygen in water =

$$\frac{16 \times 100}{18} = 88.81\%$$

The total of the percentages found should equal 100 per cent. However, a result close to this is accurate enough for the present.

SYMBOLS AND ATOMIC WEIGHTS OF COMMON ELEMENTS

Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight
Aluminum	Al	27	Magnesium	Mg	24
Antimony	Sb	122	Mercury	Hg	201
Barium	Ba	137	Nitrogen	N	14
Bromine	Br	80	Oxygen	O	16
Calcium	Ca	40	Phosphorous	P	31
Carbon	C	12	Potassium	K	39
Chlorine	Cl	35.5	Silicon	Si	28
Copper	Cu	64	Silver	Ag	108
Hydrogen	H	1	Sodium	Na	23
Iodine	I	127	Sulfur	S	32
Iron	Fe	56	Tin	Sn	119
Lead	Pb	207	Zinc	Zn	65

Let us find the percentage composition of calcium nitrate, $Ca(NO_3)_2$.

$$\begin{array}{rcl} Ca &=& 1 \times 40 = 40 \\ 2N &=& 2 \times 14 = 28 \\ 6O &=& 6 \times 16 = 96 \\ \hline & & 164 = \text{formula weight.} \end{array}$$

Percentage of calcium =

$$\frac{40 \times 100}{164} = 24.4\%$$

Percentage of nitrogen =

$$\frac{28 \times 100}{164} = 17.1\%$$

Percentage of oxygen =

$$\frac{96 \times 100}{164} = 58.5\%$$

It is very important to the chemical manufacturer to know the percentage composition of substances he uses and makes. A label is often placed on a chemical bottle giving an analysis of its contents. Your teacher will show you labels of this kind. The method of analyzing and finding the percentage composition of complex materials is studied in advanced chemistry classes.

REVIEW QUESTIONS

1. What is the standard of relative atomic weights? **2.** What two things does a symbol represent? **3.** What is the full meaning of Pb? of N? **4.** What information is obtained from the formula for carbon dioxide, CO_2? **5.** How many different kinds of atoms are in Na_2CO_3? In CaC_2? In $(NH_4)_2SO_4$? In O_2? **6.** What is the total number of atoms in Na_2CO_3? In CaC_2? In $(NH_4)_2SO_4$? In O_2? **7.** What is the formula weight of H_2S? Of $Al(NO_3)_3$? Of N_2? **8.** What is a radical? **9.** What are the names of three radicals? How are these radicals represented by using symbols? **10.** What elements are present in hydrogen chloride? In silver iodide? **11.** What is the name of SiO_2? Of Mg_3N_2? **12.** What is the percentage composition of NH_3? Of $Mg(OH)_2$? Of H_2?

D How do atoms combine to form molecules?

The combining number of an element is the number of hydrogen atoms that one atom of an element can hold in a compound. Let us look at these formulas: HCl, H_2O, PH_3, SiH_4. In a molecule of hydrogen chloride, one chlorine atom holds on to one hydrogen atom, so we say that the combining number of chlorine is 1. In a molecule of water, one oxygen atom is joined with two hydrogen atoms, so the combining number of oxygen is 2. The combining number of phosphorus is 3 because in phosphorus hydride, one phosphorus atom is combined with three hydrogen atoms. In silicon hydride why is the combining number of silicon 4?

The combining number of an element can often be found from a formula containing no hydrogen atoms. But, in this case, the combining number of some other element must be known. Let us examine these formulas: $NaCl$, $ZnCl_2$, $AlCl_3$. In the preceding para-

graph we found that the combining number of chlorine is 1. In NaCl, one sodium atom holds one chlorine atom; therefore sodium's combining number is 1. In $ZnCl_2$, the combining number of zinc is 2, because the zinc atom is joined with 2 chlorine atoms. What is the combining number of aluminum in $AlCl_3$? Why is it 3?

The usual combining numbers of some of the common elements are given in the following table.

COMBINING NUMBERS — ELEMENTS

1	H, Hg, K, Na, Ag, Cl, Br, I.
2	Ca, Cu, Fe, Hg, Mg, Pb, Zn, O, S.
3	Al, Fe, N, P.
4	Sn, C, Si, S.
5	N, P.

Radicals also have combining numbers. Look at these formulas: $H\underline{NO_3}$, $H_2\underline{SO_4}$, $H_3\underline{PO_4}$. The radical in each formula has been underlined. The group of atoms called the nitrate radical holds one hydrogen atom, so the nitrate radical has a combining number of 1. The combining number of the sulfate radical is 2 because it is combined with two hydrogen atoms. What is the combining number of the phosphate radical? Why do we say its combining number is 3?

The table that follows gives the names and combining numbers of some common radicals. The number of lines drawn from each radical is equal to its

COMBINING NUMBERS — RADICALS

CO_3	Carbonate	2
OH	Hydroxide	1
NO_3	Nitrate	1
PO_4	Phosphate	3
SO_4	Sulfate	2
NH_4	Ammonium	1

combining number. These lines are used in structural formulas which are explained below. The ammonium radical behaves as a metal so the line representing the combining number is usually placed after the radical, thus: NH_4-. Other radicals behave as nonmetals and the line (or lines) representing the combining number is (are) placed before the radical. In formulas metals are usually placed first and nonmetals last.

Do not confuse ammonia, NH_3, a gas with sharp odor, used in refrigerating systems, and the ammonium radical, NH_4- which is found only as a part of certain compounds.

Structural formulas tell us how the different atoms are linked in the molecule. Formulas, such as H_2O, NH_3 and CO_2, sometimes called ***molecular formulas***, give the elements present in the molecules and the number of atoms of each. However, in somewhat the same way as an architect uses blue prints to show the structural plans of buildings, the chemist uses ***structural formulas*** as a way of showing how atoms are put together in formulas.

The chemist supposes that each element has a number of bonds equal to its combining number. An element of combining number 1 has one bond; of combining number 2, two bonds; and so on. These bonds are represented by straight lines drawn from a symbol or radical. Using this method we represent combining bonds of hydrogen, oxygen, nitrogen, and carbon, thus:

$$\mathrm{H}–,\ –\mathrm{O}–,\ –\overset{|}{\mathrm{N}}–,\ –\underset{|}{\overset{|}{\mathrm{C}}}–$$

and the combining bonds of the sulfate and nitrate radicals as follows: $=SO_4$ and $–NO_3$. In a structural formula these bonds represented by straight lines must all be linked together.

Combining bonds are very useful in writing formulas. Let us see how it is done. Both potassium and chlorine have combining numbers of 1. So, for potassium chloride, the structural formula is K– –Cl and the molecular formula, KCl. Calcium has a combining number of 2, then, for calcium chloride, we get, a structural formula,

```
      /Cl
Ca <
      \Cl
```

a molecular formula, $CaCl_2$. Since calcium and oxygen both have combining numbers of 2 then for calcium oxide it is Ca= =O and CaO. Study other structural formulas shown below.

Hydrogen Chloride, HCl

H – – Cl

Water, H_2O

H – – O – – H

Lead Carbonate, $PbCO_3$

Pb= $=CO_3$

Aluminum oxide, Al_2O_3

```
Al≡  =O
      >O
Al≡  =O
```

A molecular formula can often be written by picturing in the mind the structural formula. What is the formula for silver bromide? The combining number of silver is 1, as is that of bromine. The one combining bond of silver can link with one bond from bromine, giving AgBr. How is the formula for hydrogen carbonate written? The hydrogen symbol, with one bond, will have to be taken twice to furnish two bonds to link up with the two bonds of the carbonate radical, giving the formula, H_2CO_3:

Hydrogen has combining number 1
Structural formula H–
Carbonate has combining number 2
Structural formula $=CO_3$
To combine these two you need 2(H–)
Therefore the structural formula would be

```
H\
   >CO3
H/
```

and the molecular formula would be

$$H_2CO_3.$$

Can you see that zinc carbonate is $ZnCO_3$? That tin chloride is $SnCl_4$? When writing the formula for aluminum sulfate, $Al_2(SO_4)_3$, we can imagine two aluminum symbols giving 6

bonds linked with 6 bonds supplied by three sulfate radicals.

Sometimes, as you will see by the table of combining numbers, an element has the audacity to have more than one combining number. Iron has a combining number of 2, and also of 3. $FeCl_2$ is iron dichloride and $FeCl_3$ is iron trichloride. In carbon monoxide, CO, carbon has a combining number of 2; whereas in carbon dioxide, CO_2, carbon's combining number is 4. As a matter of fact, the usual combining number for carbon is 4, and it is rather unusual for carbon to have a combining number of 2. Can you see that nitrogen trioxide is N_2O_3 and nitrogen pentoxide is N_2O_5? CCl_4 is called carbon tetrachloride. By looking at the formulas above and the names that go with them, can you find the prefix that means 2? That means 3? Means 4? And also 5? Find the meaning of the word "monogamy" in the dictionary. What does the prefix "mono" mean?

Every day, chemists, somewhere, are checking formulas by experimental work. There are many compounds whose structural formulas are not yet known. You have learned to write some of the simpler formulas. Being able to write some formulas correctly will be of great assistance to you in writing chemical equations.

REVIEW QUESTIONS

1. What is meant by the combining number of an element? **2.** What is the combining number of each element or radical in the following formulas: HCl, H_2O, CH_4, $SnCl_4$, SO_3, $PbCO_3$, K_2O, $Zn(OH)_2$, Al_2O_3? **3.** What is the formula for each of the following compounds: sodium chloride, calcium bromide, aluminum nitrate, silver phosphate, copper oxide, ammonium sulfate? **4.** What is the formula for mercury dibromide? For mercury monobromide? **5.** What is the name of the compound represented by each of the following formulas: CuS, $Zn_3(PO_4)_2$, K_2CO_3, $MgCl_2$, $Ca(OH)_2$, NH_4NO_3, PbI_2? **6.** What are the formulas for the two oxides of phosphorus, and what is the name of each? **7.** What is the name of each radical in the following formulas: NaOH, $(NH_4)_2SO_4$, Ag_2CO_3, Fe_2O_3, KNO_3? Which one of these formulas has two radicals in it? Which one has no radical?

E How are chemical changes represented?

A symbol represents an atom; a formula stands for a molecule; an equation shows the way in which atoms rearrange themselves during a chemical change.

Let us distinguish again between chemical and physical changes. A physical change does not involve a change in the chemical composition of a substance. An iron bar is made up of a very large number of molecules. We can represent each molecule (each molecule of iron containing one atom) by the formula, Fe. Suppose the iron bar is changed to a powder. Each iron molecule can still be represented by the formula, Fe. When we stir powdered

iron and powdered sulfur together, as we did in Unit 3 and Part A of this unit, we get a pile of material in which the particles of iron and sulfur are side by side. Fe represents each iron molecule, and S stands for each molecule of sulfur. Since no new molecules are formed during a ***physical change*** , the formula for each kind of molecule involved remains the same.

In a chemical change, the original substances are converted into one or more new substances with new properties. When we heat a mixture of iron and sulfur, the material finally begins to glow by itself. As the iron and sulfur combine chemically, a large amount of heat is given off. The grey-black solid, which forms, is a new substance with properties quite different from either iron or sulfur. It is called iron sulfide. The formula, FeS, stands for one molecule of this compound. A chemist represents the chemical change thus: Fe + S yields FeS. This is a chemical equation. A *chemical change* involves a change in the composition of the molecules. A *chemical equation* shows how the atoms in the molecules rearrange themselves during a chemical change.

DEMONSTRATION

Pour into a flask enough sodium chloride solution to cover the bottom about ½ inch deep. Half fill a test tube with silver nitrate solution, and carefully place in the flask so that the test tube is nearly upright. Place a rubber stopper in the mouth of the flask.

Now set the apparatus, thus assembled,

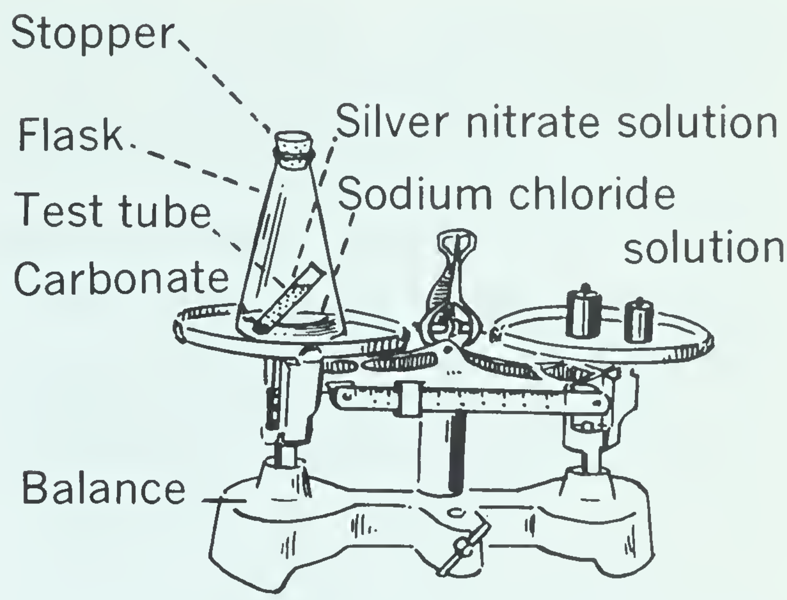


Fig. 15-12. The weight of all the substances taking part in a chemical change is precisely the same as the weight of the products of that change.

on the pan of a balance and carefully weigh it by placing weights on the other pan. Note the weight.

Tip the flask so that the two solutions mix. Make sure that nothing leaves the apparatus. What forms in the flask? Describe it. What kind of change has taken place?

Again, place the apparatus on the balance pan and weigh carefully. Note the weight. How does this weight compare with the weight before the chemical change took place?

The white, curdy solid that forms in this experiment is silver chloride, AgCl. The appearance of this new substance indicates that a chemical change has taken place. We also notice that there is no change in weight.

In an ordinary chemical change, the total weight of the substances entering the change is equal to the total weight of the products formed. This statement is known as the ***law of conservation of matter.*** You learned, in Unit 1, that when matter is destroyed, energy is produced. Because of this discovery,

scientists combined the two old laws of matter and energy into one new law: *matter and energy cannot be created or destroyed by ordinary means, but they can be changed:* However, the changing of matter into energy cannot be noticed in the ordinary laboratory. For example, the amount of matter changed into energy when a fuel burns cannot be weighed on the most sensitive balance. When writing chemical equations, we use the law stated at the beginning of this paragraph.

The chemical change comes first, and your representation of it in the form of an equation second. You should clearly understand this before starting to write equations. We study chemical changes in the laboratory, or elsewhere, and use the information thus obtained in equation writing. Before writing an equation we must know three things: (1) that a chemical change takes place; (2) what substances enter into the change and what products are formed; and (3) the formulas of the starting substances and of the products.

In writing a chemical equation there are three steps: (1) the ***word equation***; (2) the ***formula equation*** ; and (3) the ***balanced equation***. In the word equation, the names of the substances (sometimes there is only one) entering into the change connected by a + sign are listed. Then an arrow is placed to the right of these names. After the arrow are written the names of products, using a + sign, if necessary. For example, in Unit 11, you learned that water is separated into hydrogen and oxygen by an electric current. The word equation for the decomposition of water is:

$$\text{water} \rightarrow \text{hydrogen} + \text{oxygen}$$

To write a formula equation correct formulas for reacting substances and products must be known. In Part D you learned to write formulas. The formula for water is H_2O; for hydrogen H_2; and for oxygen, O_2. For the chemical change in which water is separated into its elements the formula equation is:

$$H_2O \rightarrow H_2 + O_2$$

An equation must always be balanced. Although the composition of molecules may alter, the law of conservation of matter tells us that no particle of matter can be created or destroyed in an ordinary chemical change. No atom is gained or lost. Balancing an equation is a matter of seeing that the same kind and number of atoms are shown on both sides of the arrow. Formulas representing molecules must not be altered. The formula equation is balanced by placing whole numbers, where necessary, in front of the correct formulas. Let us look at the formula equation for the decomposition of water. There are two hydrogen atoms on each side. But, on the left there is one oxygen atom, while on the right there are two. To get the same number of oxygen atoms on each side we must take two water molecules, $2H_2O$, on the left side.

$$2H_2O \rightarrow H_2 + O_2$$

Now we have four hydrogen atoms on

the left and two on the right. A further adjustment is necessary. Two hydrogen molecules, $2H_2$, must be taken on the right side. The balanced equation is:

$$2H_2O \rightarrow 2H_2 + O_2$$

How many hydrogen atoms on each side? Oxygen atoms on each side?

Let us do another example. When iron rusts, it joins with oxygen in the air forming the reddish-brown solid, called red iron oxide. We write:

Iron + oxygen → red iron oxide

$$Fe + O_2 \rightarrow Fe_2O_3$$

Let us balance for iron:

$$2Fe + O_2 \rightarrow 2Fe_2O_3$$

Then balance for oxygen:

$$2Fe + 3O_2 \rightarrow 2Fe_2O_3$$

It is now necessary to rebalance for iron:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

How many iron atoms on each side? Oxygen atoms on each side?

Later, when you become more familiar with equation writing, you may omit the word equation. You will learn to write the formula equation and then balance it in a single line. You should be sure, however, that you know the name of the substance represented by each formula. Remember, if your first attempt at balancing an equation fails, try again by balancing for an element other than the one first considered.

Correct equations for some chemical changes you have observed are:

(1) Mixing solutions of silver nitrate and sodium chloride

$$AgNO_3 + NaCl \rightarrow AgCl\downarrow + NaNO_3$$

The downward-pointing arrow indicates a solid substance (a precipitate) resulting from a chemical change in solution.

(2) Preparing oxygen by heating potassium chlorate

$$2KClO_3 \rightarrow 2KCl + 3O_2\uparrow$$

The upward-pointing arrow indicates a gas leaving a chemical change.

(3) Burning of phosphorus in air

$$4P + 5O_2 \rightarrow 2P_2O_5$$

(4) Heating a mixture of copper oxide and charcoal

$$2CuO + C \rightarrow 2Cu + CO_2\uparrow$$

Can you name the substance represented by each formula in the equations above?

The chemical equation is of great value to the chemical engineer. By means of it, he calculates the quantity of various substances required for making a certain chemical product. If, for example, the engineer is in charge of a plant producing lime, he can, by means of a chemical equation, calculate the quantity of limestone required and how much lime he may hope to obtain. We will have to leave calculations using equations for future study.

REVIEW QUESTIONS

1. What happens to molecules in a chemical change? In a physical change? **2.** What is a chemical equation? **3.** What three things must you know before you can write a chemical equation? **4.** Why should an equation be balanced? **5.** Write the formula equation for each chemical change and balance:

sulfur + oxygen → sulfur dioxide
sodium + oxygen → sodium oxide
potassium chloride → potassium + chlorine
calcium carbonate → calcium oxide + carbon dioxide
phosphorus + bromine → phosphorus tribromide
aluminum + oxygen → aluminum oxide

6. Balance these formula equations:

$Cu + O_2 \rightarrow CuO$
$Pb + O_2 \rightarrow Pb_3O_4$
$Zn + HCl \rightarrow ZnCl_2 + H_2$
$HgO \rightarrow Hg + O_2$
$Zn + Cl_2 \rightarrow ZnCl_2$
$BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + NaCl$

7. What is the error in this equation:

$$H_2 + O_2 \rightarrow H_2O?$$

Correct it.

F What are the properties of acids, bases and salts?

All acids contain the element hydrogen. Look at the labels of the acid bottles in the laboratory and you will notice that the formulas of all of them begin with H for hydrogen.

Thus, *sulfuric acid* is H_2SO_4, *hydrochloric acid* is HCl, and *nitric acid* is HNO_3. Sulfuric acid is a solution of the thick, oily liquid called hydrogen sulfate, H_2SO_4. Hydrochloric acid is a solution in water of the sharp, choking gas called hydrogen chloride, HCl; nitric acid is a water solution of the liquid called hydrogen nitrate, HNO_3. You will notice that the formula for the compound dissolved in water, and the acid, is the same. In most cases it is not necessary to make a distinction between the name of the compound and its water solution, and both are often called acids.

Sulfuric, hydrochloric, and nitric are all strong acids which chemists use in laboratories and in industry too. But there are many others, some of which are weaker acids, such as acetic acid, $HC_2H_3O_2$, in vinegar; carbonic acid, H_2CO_3, in plain soda water; and tartaric acid, $H_2C_4H_4O_6$, which comes from grapes. The formulas for all these begin with H. Some acids have the letter H mentioned later in the formula, too, because they contain additional hydrogen atoms joined in the molecule in a different way.

Acids are recognized by their properties. You know how sour lemon juice tastes. That is due to the *citric acid* in ripe lemons. Acids generally taste sour. This is one of their properties.

DEMONSTRATION

Taste a few drops of lemon juice. Touch the end of your tongue to a small crystal

of tartaric acid. Does it have a similar taste? Add *just one drop* of dilute sulfuric acid to a glassful of water, and taste the diluted acid after stirring.

Sulfuric acid, like many others, is such an active chemical that it would burn our lips, but when we dilute it with water we notice that it has a sour taste like the acids in fruits.

Acids turn blue litmus paper red. When you dip a piece of blue litmus paper in a dilute solution of any acid, the litmus paper will turn red. Here is a good way to tell when an acid is present, and it is safer than the taste test.

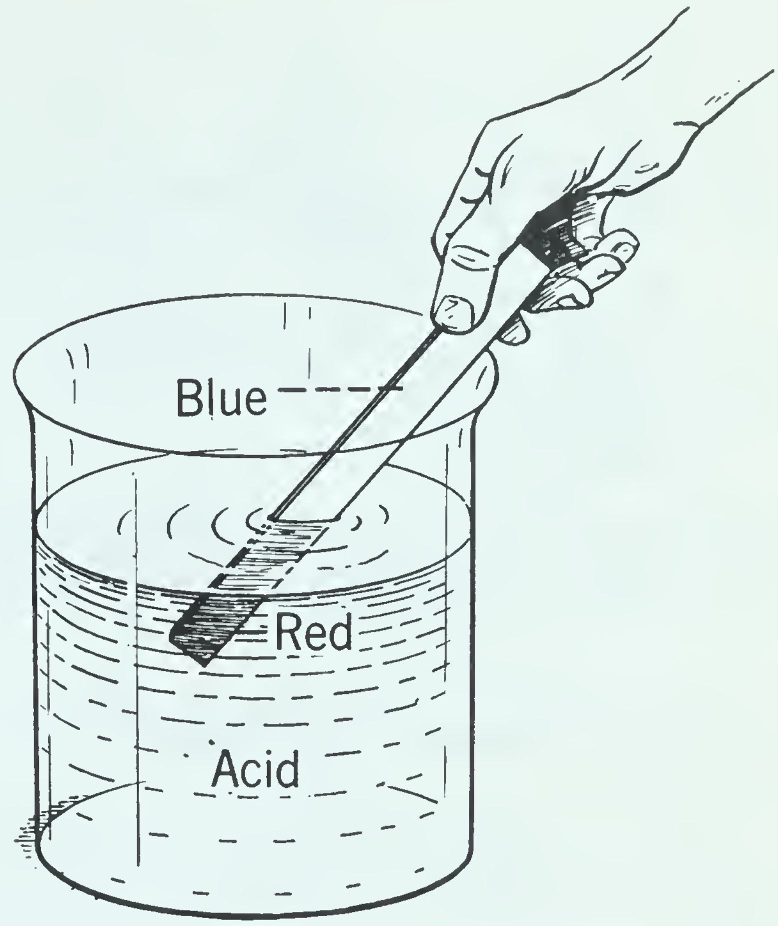


Fig. 15-13. Acids turn blue litmus red.

PUPIL ACTIVITY

Dip strips of blue litmus in dilute solutions of sulfuric, hydrochloric, and nitric acids. Results?

Take strips of litmus paper home and try them on different liquids. Lemon juice, onion juice, tomato juice, diluted molasses, and vinegar are good liquids for this test. Do you find acids in any of these?

Many common metals gradually disappear when you put them into an acid. Bubbles of gas are set free, too, as the acid reacts with the metal. We say that acids *corrode* metals, which means that they dissolve or eat them away by chemical action. If you collect some of this gas that comes off, you will find that a mixture of it with air makes a little explosion when you light it. This gas is *hydrogen*. Since all acids contain hydrogen, we get this gas from almost any acid we add to most metals.

DEMONSTRATION

Add 2 or 3 iron nails to a beaker containing 1 part of hydrochloric acid mixed with 5 parts of water (see Fig. 15-14). Can you see any bubbles of gas coming off? Let the beaker stand for a day or two and then see if the nails have been corroded by the acid.

In another beaker put 2 or 3 small pieces of zinc and then add some more of this diluted acid. Does the acid act faster on the zinc?

Pour some of this diluted acid in a test tube and then drop in a piece of magnesium ribbon. Result? Hold a lighted match above the test tube. Result?

Some metals react faster with acids than others. Zinc is a more active metal than iron. After a few minutes, the magnesium ribbon disappeared as the acid reacted on it. Thus, magne-

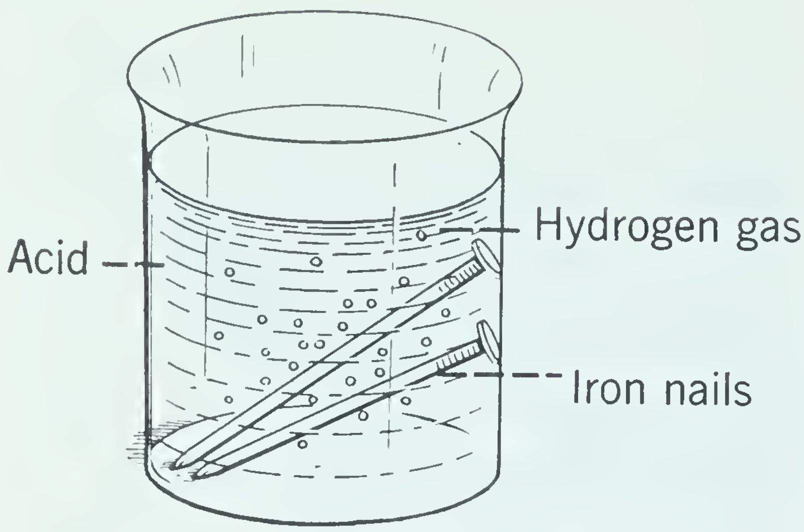


Fig. 15-14. Acid acts on iron nails setting free bubbles of hydrogen gas which rise to the surface of the liquid.

sium is even more active than iron or zinc.

The equation for the chemical change involving iron and hydrochloric acid is:

$$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$$

Can you write the equation for the reaction of hydrochloric acid on zinc? On magnesium?

Carbonates are easily attacked by acids. Bubbles of gas are set free as an acid affects a carbonate. If you collect some of this gas, you will find that the gas does not burn when a lighted match is brought near it; and you will notice, too, that the gas puts out the lighted match. This gas also turns limewater milky. It is called carbon dioxide, CO_2.

DEMONSTRATION

Place some marble chips in a test tube containing 1 part hydrochloric acid and 5 parts water. Can you see bubbles of gas coming off? Hold a lighted match above the test tube. Result? Hold it in the mouth of the test tube. Result? Place a one-hole stopper fitted with a delivery tube in the mouth of the test tube. Bubble the gas through limewater in another test tube. Result?

Marble used in decorating buildings and for gravestones is a form of impure calcium carbonate, $CaCO_3$. Limestone, coral, pearls, egg shells are largely calcium carbonate. Hydrochloric acid reacts chemically with all these substances containing calcium carbonate in this manner:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2\uparrow$$

Cleopatra is supposed to have placed her pearls in vinegar. What happened?

Bases have a bitter taste. Bases are not as common in everyday life as acids, but they form an important class of compounds too. Limewater is a solution of the base called calcium hydroxide, $Ca(OH)_2$. Sodium hydroxide, NaOH, the white solid called household lye, and potassium hydroxide, KOH, another white solid, are two other well-known bases. Household ammonia, formed when the sharp-smelling gas—ammonia, NH_3—dissolves in water.

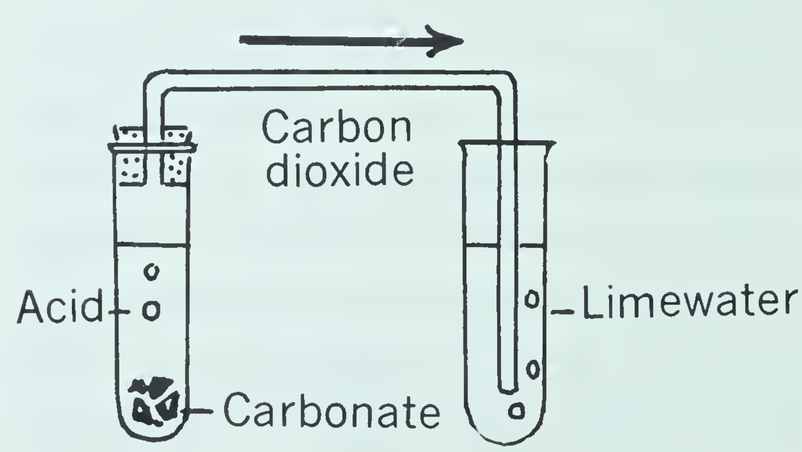


Fig. 15-15. Acid acts on a carbonate, freeing carbon dioxide gas which turns limewater milky.

contains the base, ammonium hydroxide, NH_4OH.

$$NH_3 + H_2O \rightarrow NH_4OH$$

You will notice that the formula of each of these bases contains the group of atoms which we write as OH. This OH group is called the ***hydroxide*** or ***hydroxyl radical.*** Either name is a good one because the radical contains both oxygen and hydrogen.

Just as some acids are too strong to taste without diluting them with water, so we find that some bases will burn our lips also. Bases that attack the skin like this are said to have a *caustic action*. Caustic means to dissolve or eat away such substances as skin, wool, and hair. Now you see why your mother is so careful to wash her woolen blankets with soap that contains no free bases, such as harsh laundry soaps do. Bases react with grease to form a kind of soap that washes away. That is why laundry soaps are so effective for washing greasy overalls. Bases in solution have a slippery feeling when your finger tips are dipped into the solution and then rubbed together. Water solutions of bases also turn red litmus paper blue. Here, then, is a good way to test for a base.

DEMONSTRATION

Taste some limewater. How does it taste? Dip a strip of red litmus paper in a few drops of dilute sodium hydroxide solution. How do bases affect litmus? Rub a drop of dilute sodium hydroxide solution between your thumb and forefinger. How does it feel?

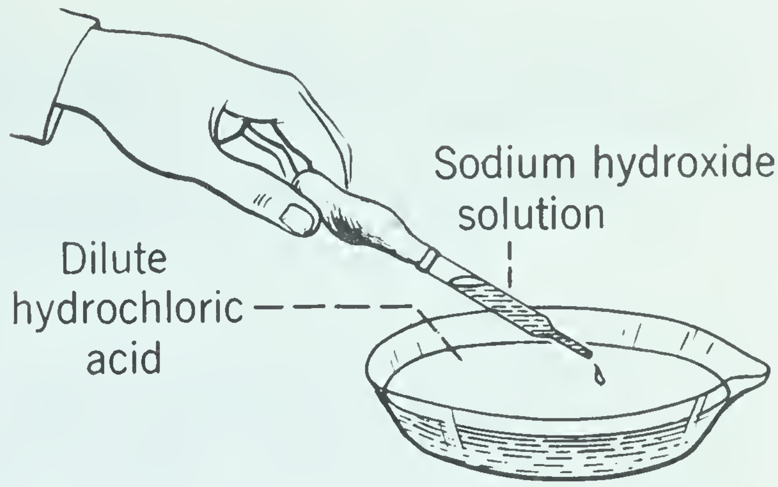


Fig. 15-16. When you add dilute sodium hydroxide to dilute hydrochloric acid, they both neutralize each other.

Make a solution by dissolving 1 part of solid sodium hydroxide with 10 parts of water. (CAUTION: do not handle the sodium hydroxide with your fingers; use forceps!) Use a Pyrex beaker for the solution. Now heat the solution to boiling over a burner. Then, remove the burner and add a strip of woolen cloth about 2 inches square. Stir the liquid carefully with a glass rod. What happens to the wool? Be careful not to spatter this liquid as it is very caustic. Bases do not affect cotton the way they do wool. Try this experiment with a piece of cloth that is part wool and part cotton. What difference do you notice? How could you tell whether a cloth is all wool, or part wool and part cotton?

Bases and acids neutralize each other. When you add a base, such as sodium hydroxide solution, to an acid drop by drop, you reach a point when the mixture no longer turns blue litmus red. We say that the acid neutralizes the base, but it is just as correct to say that the base neutralizes the acid.

We can write this kind of chemical change, called neutralization, in the form of a general word equation:

An acid + a base → a salt + water

If you neutralize hydrochloric acid with sodium hydroxide, you write the chemical equation like this:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

If you study chemistry later, you will write many such formula equations. If you add just the right number of molecules of a base to an acid, the equation above shows that the products will be a salt and water. There will not be any acid or base left. That is why we say they neutralize each other.

DEMONSTRATION

Add about 30 drops of dilute sodium hydroxide solution to a porcelain evaporating dish. Then, add dilute hydrochloric acid drop by drop (as shown in Fig. 15-16), until the solution no longer turns litmus blue. Now, put the evaporating dish on a ring stand and heat until the liquid all boils away (Fig. 15-17). Use a small flame when the liquid is almost evaporated to avoid spattering. Let the dish cool, and then touch a moistened finger to the white solid left, and taste it. How does it taste?

What is the name of the product that is left in the dish? What happened to the water that was produced?

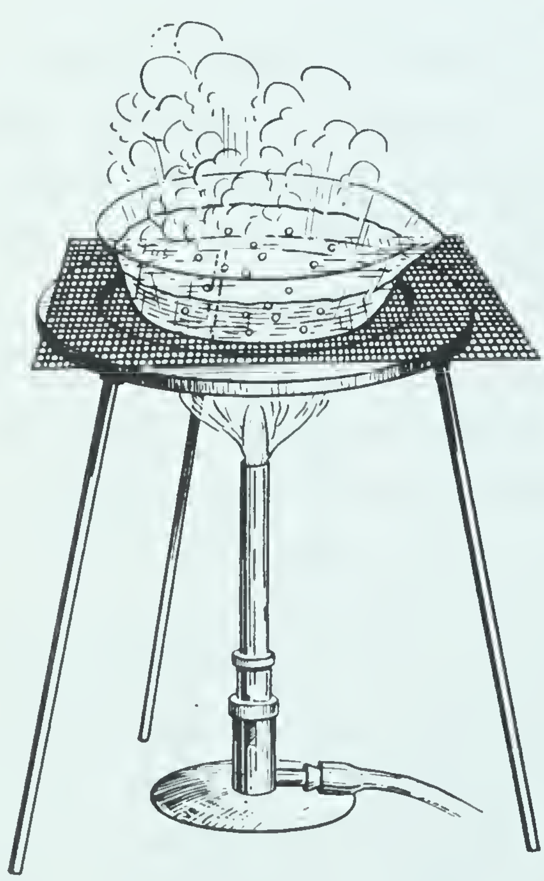


Fig. 15-17. When you heat an acid and a base until all the liquid boils away, the product that remains is a salt.

There are a great many different compounds called salts. We are all familiar with table salt. It has the chemical name *sodium chloride* and the formula NaCl. But suppose we write the formula KCl. Then, we have a different salt called *potassium chloride*. Thus we can make a great many different salts by using a different metal than sodium. *Zinc chloride, copper chloride*, and *lead chloride* are all salts that are known to the chemist.

You can also change the Cl part of the compound too, and use Br for bromide. Then we have NaBr, or *sodium bromide*. You can make a bromide for each of the metals, too, such as *iron bromide, silver bromide*, and *nickel bromide*. From this you may begin to wonder how many salts there are. Chemists know hundreds and hundreds of different salts. Some are useful, others are of little interest because we do not have any particular use for them.

PUPIL ACTIVITY

Examine the bottles of different salts from the laboratory stockroom. Note the names, formulas, and the appearance of

the different salts. You should be able to make a list of at least 10 different salts from the bottles your teacher puts on the table for you to examine. Do not open the bottles, just look at them, and read the labels.

All salts do not have the same taste, the way acids do. Some taste salty, others are bitter. Salts differ in color. Some are white solids, others are blue, pink, or green. Water will dissolve some salts easily, but many will not dissolve in water at all. Thus we see that salts each have their own individual properties.

Salts can be made by adding an acid to a base. That is one way in which all salts are alike. The following equations represent the chemical changes taking place in the preparation of calcium chloride and ammonium nitrate:

$$2HCL + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$$

$$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$$

REVIEW QUESTIONS

1. What element is present in all acids? **2.** List four properties of acids. **3.** List three properties of bases. **4.** How could you identify the presence of an acid? Of a base? **5.** What effect has a neutral solution on litmus paper? **6.** What is meant by neutralization? **7.** How can you make a salt? **8.** Write an equation for each of the following chemical changes: (a) Action of sulfuric acid on zinc. (b) Action of nitric acid on calcium carbonate. (c) The neutralization of sulfuric acid by potassium hydroxide.

G What are some of the important chemical substances?

Salt is necessary in our diet. We use salt to flavor some foods, and also to keep such foods as ham, corned beef, and butter from spoiling. More important, though, salt is necessary for the human body. Without it we would die. Salt is dissolved in the bloodstream. It is also present in tears and perspiration. From salt our bodies make small amounts of hydrochloric acid that help in the digestion of food.

There are many uses for salt. It melts the ice on the streets in winter. A mixture of chopped ice and salt can be used to freeze ice cream. Perhaps the biggest use for salt in industry is as a raw material for making other compounds. The chemical name for table salt is *sodium chloride* and its formula is NaCl. Thus, we can use it to prepare sodium and also chlorine. In addition, we use it to make many other sodium compounds.

Common salt is plentiful. In each hundred pounds of sea water there are about three pounds of common salt. Hence we can get all the salt we want by just evaporating sea water. Of course, it takes a lot of fuel to do this, so we usually find it cheaper to get our salt from some other sources.

Much salt is dug from salt deposits, just as coal is mined. These deposits are found in many places in the world. Salt rock from a mine is a dark gray

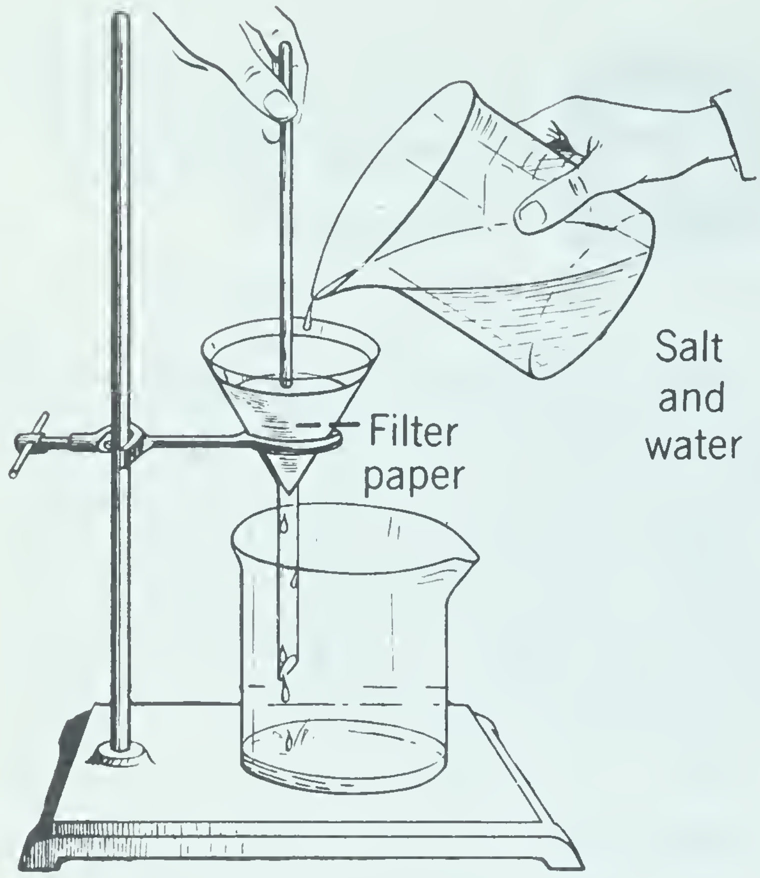


Fig. 15-18. Some of the impurities from crude salt may be eliminated by filtering.

solid because of impurities. If this crude salt is dissolved, filtered, and then evaporated, we can separate it from the impurities. By repeating this process several times, we get the snow-white product so necessary to our tables.

DEMONSTRATION

Add about a pound of the crude salt (rock salt will do) to a large glass beaker. Then add about three times that volume of hot water. Stir the mixture with a glass rod to dissolve the salt. It takes some time for all the salt to dissolve. Now arrange a funnel with a filter paper and filter the solution into another large beaker (see Fig. 15-18). Do you find any dirt left on the filter paper? Some of the impurities, however, are now dissolved in the water together with the salt.

Put the beaker on a tripod so that you can heat it with a burner. Boil the solution until about two-thirds of the liquid has boiled away, or until there are a lot of salt crystals mixed with the remaining liquid. Filter this mixture and collect the salt on the filter paper.

Most of the dissolved impurities remain in the liquid which filters through the paper because they do not separate from the solution as easily as the salt. Notice that the salt you obtain is much purer than the crude salt you started with. But, to make a still purer salt, we should repeat this process over again. In salt works this process is repeated three or four times to get pure table salt.

Salt is the raw material for making other compounds. Baking soda is a white powder that has the formula $NaHCO_3$ and the chemical name *sodium bicarbonate* or sodium hydrogen carbonate. We use salt as the raw material for making it. The operation is not a simple one, but by pumping ammonia gas and carbon dioxide into a cold solution of salt, we can get the sodium bicarbonate to settle out as a white solid. This crude baking soda is then purified while the other products are recovered and used over again.

Baking soda acts as a mild base when we dissolve it in water. If we add it to an acid, bubbles of carbon dioxide gas escape in great numbers. We say that the mixture ***effervesces*** (eff-er-*vess*-sez). Some people use a solution of baking soda in water to overcome the condition called "sour stomach." This is a bad health practice.

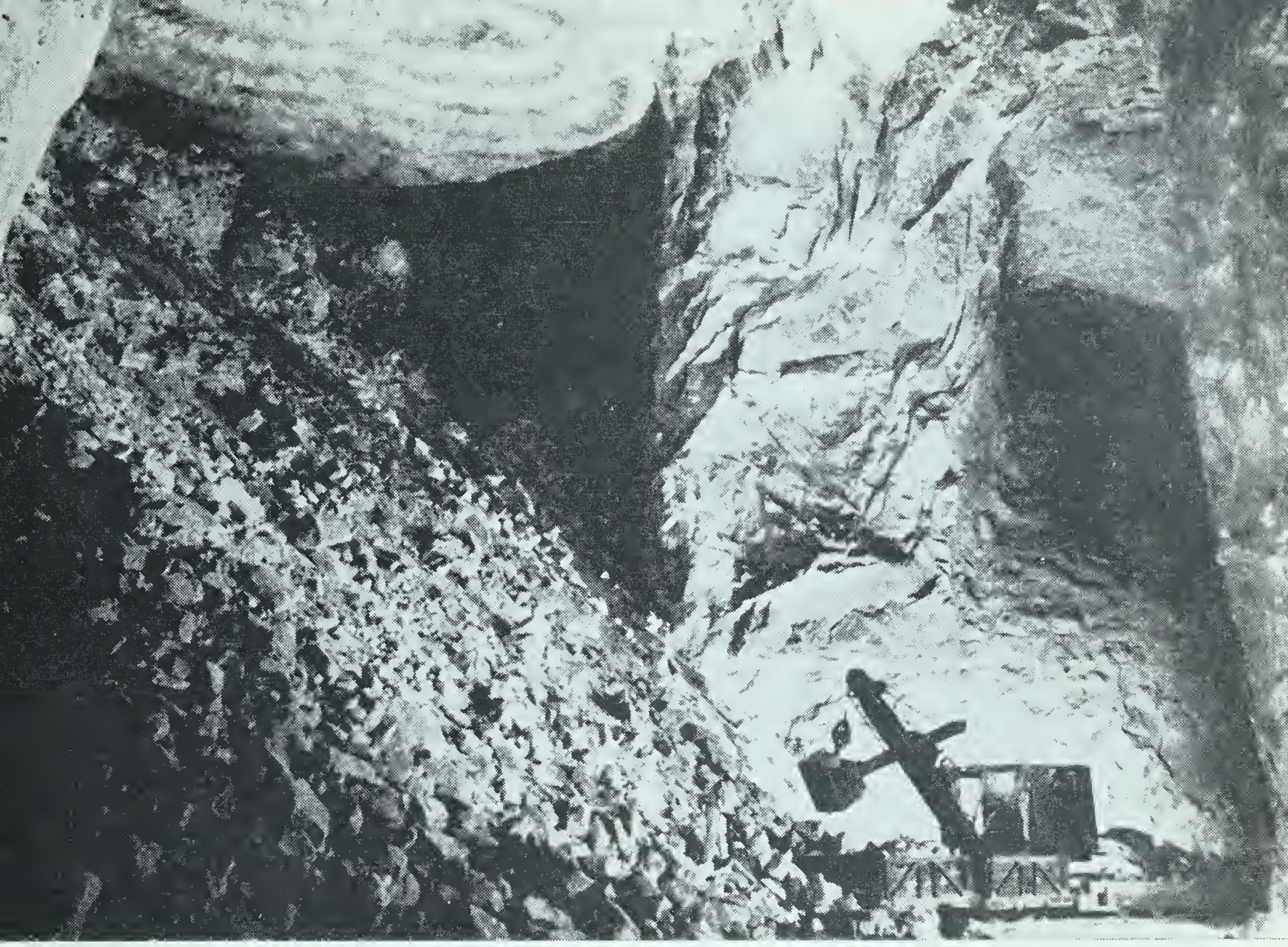


Fig. 15-19. Salt is dug from deep deposits much like coal is mined.

DEMONSTRATION

Add a spoonful of baking soda to a beaker one-third full of water. Then add dilute hydrochloric acid, a few drops at a time, as long as bubbles of gas are produced. When the right amount of acid has been added, the solution will no longer turn red litmus blue.

When neutralization is complete, pour a little of the liquid in a porcelain evaporating dish, and boil it down to dryness. Note the taste of the white solid that remains.

The equation for the change is as follows:

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$

When a cook says "soda" she means *sodium bicarbonate*, $NaHCO_3$, but when a manufacturer of scouring powder says "soda," he means *sodium carbonate*, Na_2CO_3. You must be careful to distinguish between these two powders because they have different properties. Perhaps it is best to use the chemical names and then you will not get them confused. Sodium carbonate acts like a strong base when you add it to water. It is useful for removing grease from sinks and for scouring pots and pans. One of the most important uses for sodium carbonate is for making glass.

Baking powders are mixtures of baking soda and an acid substance. When your mother makes a cake, she

Fig. 15-20. When water is added to baking powder, the mixture effervesces.

measures out the right amount of baking powder and mixes it with the flour. When water or milk is added to the batch, effervescence occurs, and bubbles of carbon dioxide gas make the cake batter a spongy mass. During the baking, the cake "rises" still more as the heat expands the bubbles of gas.

All baking powders contain sodium bicarbonate mixed with another powder that will act like an acid. Sometimes tartaric acid, a white powder obtained from grapes, is the other main ingredient. Of course, you must keep the powder dry until you are ready to use it.

DEMONSTRATION

Make a simple baking powder by mixing on a large sheet of paper one spoonful of baking soda, two spoonfuls of tartaric acid powder, and one spoonful of cornstarch. Mix the three substances thoroughly. Add this baking powder you have made to a large beaker that is half-full of water. Note the bubbles of gas that come off.

Slaked lime is the cheapest base. Large deposits of limestone occur in many places. This rock is quarried and brought to a special kind of furnace called a *lime kiln*. Limestone is a form of *calcium carbonate*, $CaCO_3$. When it is heated in the kiln, carbon dioxide comes off and calcium oxide is left. The chemist expresses this change as follows:

$$CaCO_3 \underset{\text{(heated)}}{\rightarrow} CaO + CO_2$$

The calcium oxide is a white solid that unites with water so vigorously that much heat is set free. This heat changes some of the water to steam. Calcium oxide is often called *quicklime*. The change that occurs is as follows:

$$CaO + H_2O \rightarrow Ca(OH)_2$$

When we add water to the quicklime, we say that we "slake the lime." The calcium hydroxide that is formed is called *slaked lime* or *hydrated lime*.

DEMONSTRATION

Put a lump of quicklime in a glass beaker. Pour a few drops of water slowly over the lime and note what happens after a minute or two. It may be necessary to add a little more water to get a good result. Does the quicklime crumble to a powder? Do you see any vapor rising from the lime? What is the product?

You may have seen plasterers mixing water with quicklime to make slaked lime for plaster. Slaked lime is also used whenever we want a cheap base.

Common glass is made from sodium carbonate, lime, and sand. Who would ever think as he looks through a glass window that this transparent material is made from sodium carbonate, lime, and sand? Yet, when these are melted together in a very hot furnace, the product forms glass. The mixture must be heated for several days to get rid of the bubbles of carbon dioxide gas that are set free.

The hot glass forms a pasty liquid that can be blown into molds to make bottles, glass dishes, and other objects. Sheet glass is made by dipping a horizontal iron rod into the pasty mixture, and then raising it slowly. The glass clings to the rod and forms a sheet.

PUPIL ACTIVITY

See how many different kinds of glass you can assemble for the class to examine. Bottles of different colors, glass insulators, glass dishes, glass wool, and glass cloth are suitable. Your teacher will show you a fine glass lens from a projection lantern, too.

Besides common glass, there are several other kinds that are made from different materials. Borax and aluminum oxide melted together with sand make Pyrex glass that we use for baking dishes. It expands much less than ordinary glass when heated; that is why we can heat it in the oven without breaking it. A more lustrous glass is made from potash and lead oxide, together with pure sand. Your mother's best water goblets are probably made from this kind of glass.

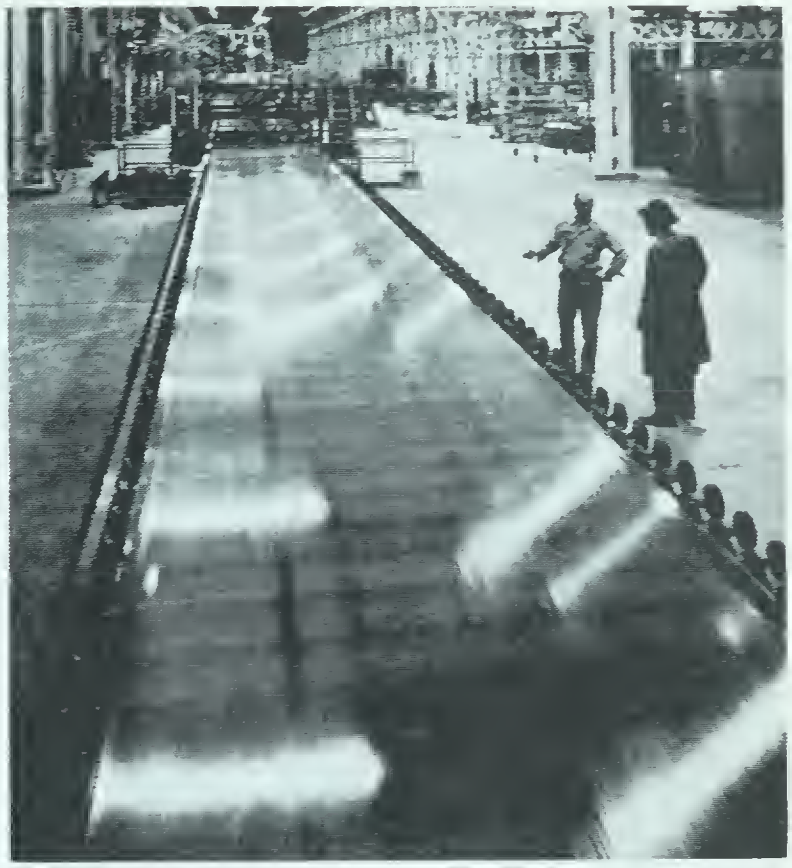


Fig. 15-21. The above photograph shows a ribbon of newly cast plate glass. It is moving on into a special machine for grinding the surfaces smooth and parallel.

Soap is made by heating together a fat and an alkali. In former times soap was made at home by boiling scraps of fat in a huge kettle with a solution of *lye*. Lye is a strong *alkali* (*al*-kah-lye). An ***alkali*** is a base that will react with fats and grease to form soap.

DEMONSTRATION

Dissolve two teaspoonfuls of lye in a cup of water. Heat to hasten the dissolving. Cool and add one cup of melted fat such as tallow, lard, or cottonseed oil. Stir the mixture well while heating it to a temperature of about 100° F. until it is fairly thick. CAUTION: Be careful not to let it splatter into your eyes. Set the resulting soap aside to harden for about a week. Cut into small cakes. Try making a lather with it in some water softened with borax. Result?

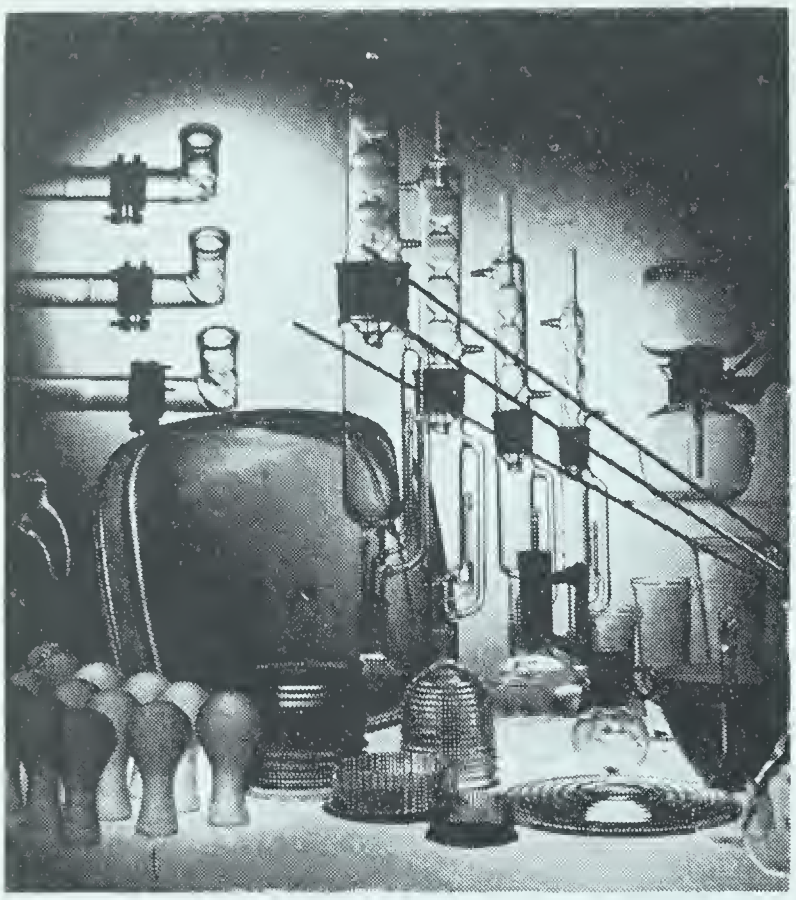


Fig. 15-22. Glass can be blown into various shaped molds. How many of these objects can you recognize?

When you heat a fat or oil and an alkali, the soap formed soon thickens. You can then separate it from the rest of the mixture. Salt is added to help separate the soap. Sometimes air is blown through a batch of soap while it is still soft. This produces floating soap. A cake of soap may contain as much as 40 per cent water.

REVIEW QUESTIONS

1. What methods are used to obtain common salt? **2.** How is crude salt purified to make table salt? **3.** What is the effect of an acid on baking soda? **4.** How is quicklime slaked? **5.** What three materials are melted together to make common glass? **6.** How is glass made in the form of sheets? **7.** What materials are used in making baking powder? Why must the powder be kept covered when not in use? **8.** How does Pyrex glass differ from the glass in window panes?

H How does the chemist make plastics?

Celluloid was the first modern plastic. When cotton fibers react with a mixture of nitric and sulfuric acids, *cellulose nitrate* is produced. This material dissolves in a mixture of alcohol and ether. As the liquid evaporates, a gummy residue is left. If you mix camphor with this gummy residue, the product is celluloid. You can form celluloid into sheets, rods, and blocks, or mold it to any shape desired. Toilet articles and small toys are often made from celluloid. But celluloid has one important fault. It burns very easily. That is why other plastics are more popular today.

DEMONSTRATION

Collodion (koll-*oh*-dee-un) from the drug store is a solution of cellulose nitrate in alcohol and ether. Pour a little collodion on a glass square, and move the glass about so that the liquid spreads over most of the glass. Let the square stand until all the liquid has evaporated. Then peel off the film of gummy material that remains. This gummy residue is a plastic that resembles celluloid. Hold a piece of it in the flame, using forceps. What is the principal disadvantage of celluloid?

Other plastics are made by complex processes that we cannot use in the classroom.

There are two main classes of mod-

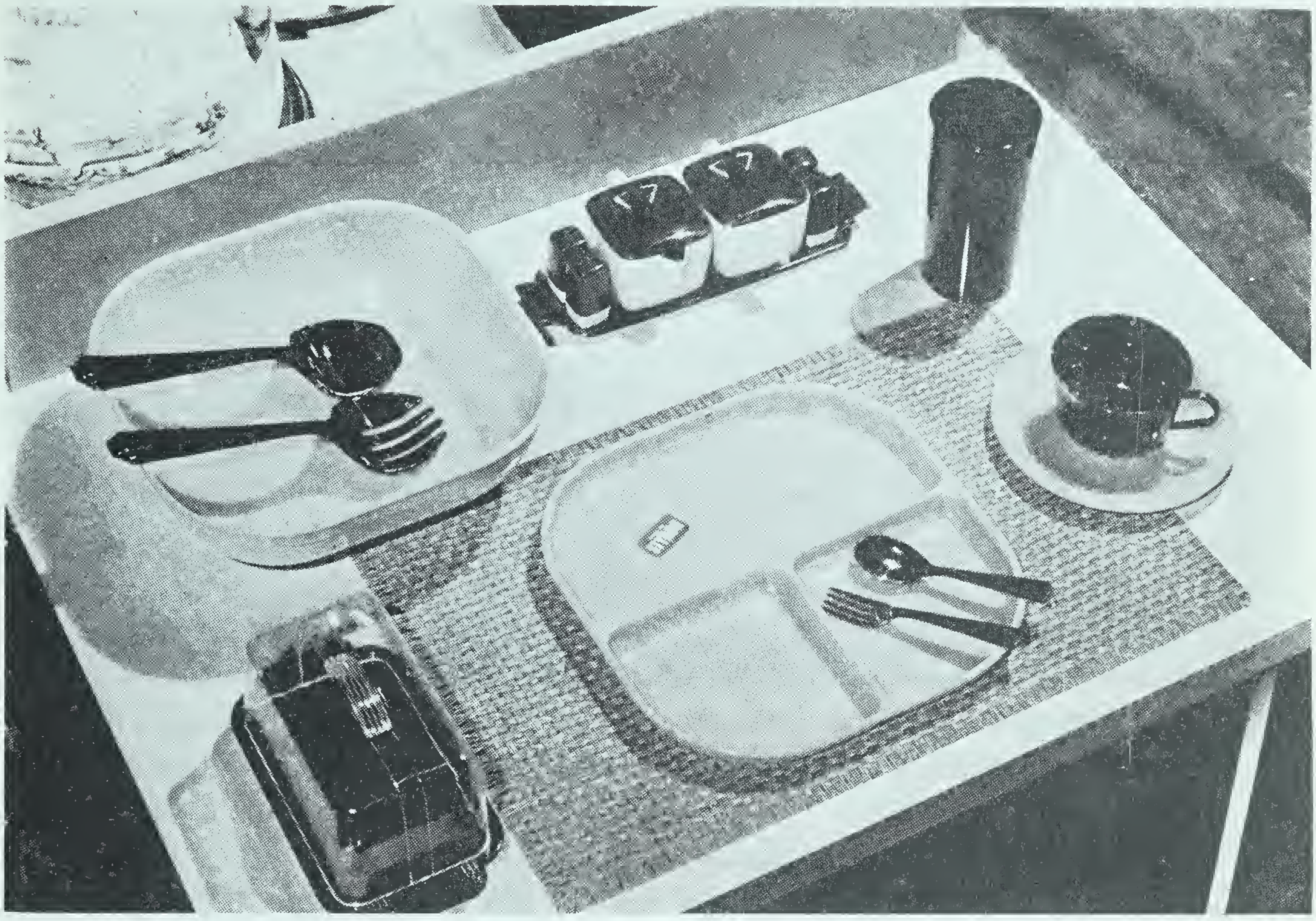


Fig. 15-23. Colorful houseware is made from a polystyrene plastic.

ern plastics. All our modern plastics can be divided into two groups. One of these is called thermoplastic, which means that we can soften such plastics by heating them gently. Eyeglass frames are thermoplastic. When they fit too tightly over the ears, the bows can be softened in warm water and bent into a more comfortable shape.

The other group of plastics, and they are the more numerous today, are called *thermosetting.* A thermosetting plastic is made by heating a molding powder and forming it into the desired shape. As it cools, it "sets," and cannot again be changed in shape. A good example of a thermosetting plastic is the black outer case of your telephone set. Radio and television cabinets are also made of this type of plastic.

Modern plastics are made from complex chemicals. Although we use plastic articles every day, the chemicals from which they are made are not simple. Usually two or more chemicals are combined to make the plastic. We will mention a few so that you may see what wonderful progress chemists have made in this field. *Bakelite* is a thermosetting plastic that is made from *phenol* (*fee*-nol) and *formaldehyde.* We use it for making telephone sets, gears, radio cabinets, fountain pens, and phonograph records, besides many other things. We can also make it in a liquid form that makes an excellent floor varnish.

False teeth are now set into a plastic that is colored pink, and shaped to fit the mouth of the wearer. This is a

thermoplastic material that can be softened and changed in shape. The plastic used for this purpose is *methyl methacrylate* (*meth*-ill meth-*ak*-rilate). You need not learn this long name; we give it only to show you that plastics are not simple substances. The same plastic is used for those transparent curved windows in front of the pilot on an airplane. Also, fancy jewel boxes are often made from this plastic.

The white plastic case of the computing scale you see in a supermarket is made from a mixture of urea and formaldehyde. This plastic is very hard and stands sharp blows without breaking. Still another kind is *vinylite* (*vine*-ee-lite) which is used to make transparent belts and suspenders. The tiles on the shower stall in your bathroom may be made of a plastic called *polystyrene* (pol-ee-*sty*-reen). From the examples given above, you can see that the chemist has developed many new plastics that are complex compounds with interesting properties. With continued research, newer and better plastics will be produced.

PUPIL ACTIVITY

Look around your home and see how many articles you can find that are made from a plastic. You should be able to make a list of at least a dozen articles.

Many new textiles are really plastic materials. Besides plastic molded objects, the chemist has learned how to form plastics into fine threads to be woven into cloth. The method is to force a suitable plastic liquid through very small holes in a metal plate. As the liquid strikes the air after passing through the holes, or when it is dipped in a liquid chemical, it changes to a solid. This is much like the way a spider spins its web, or the way a silkworm produces silk. But science has

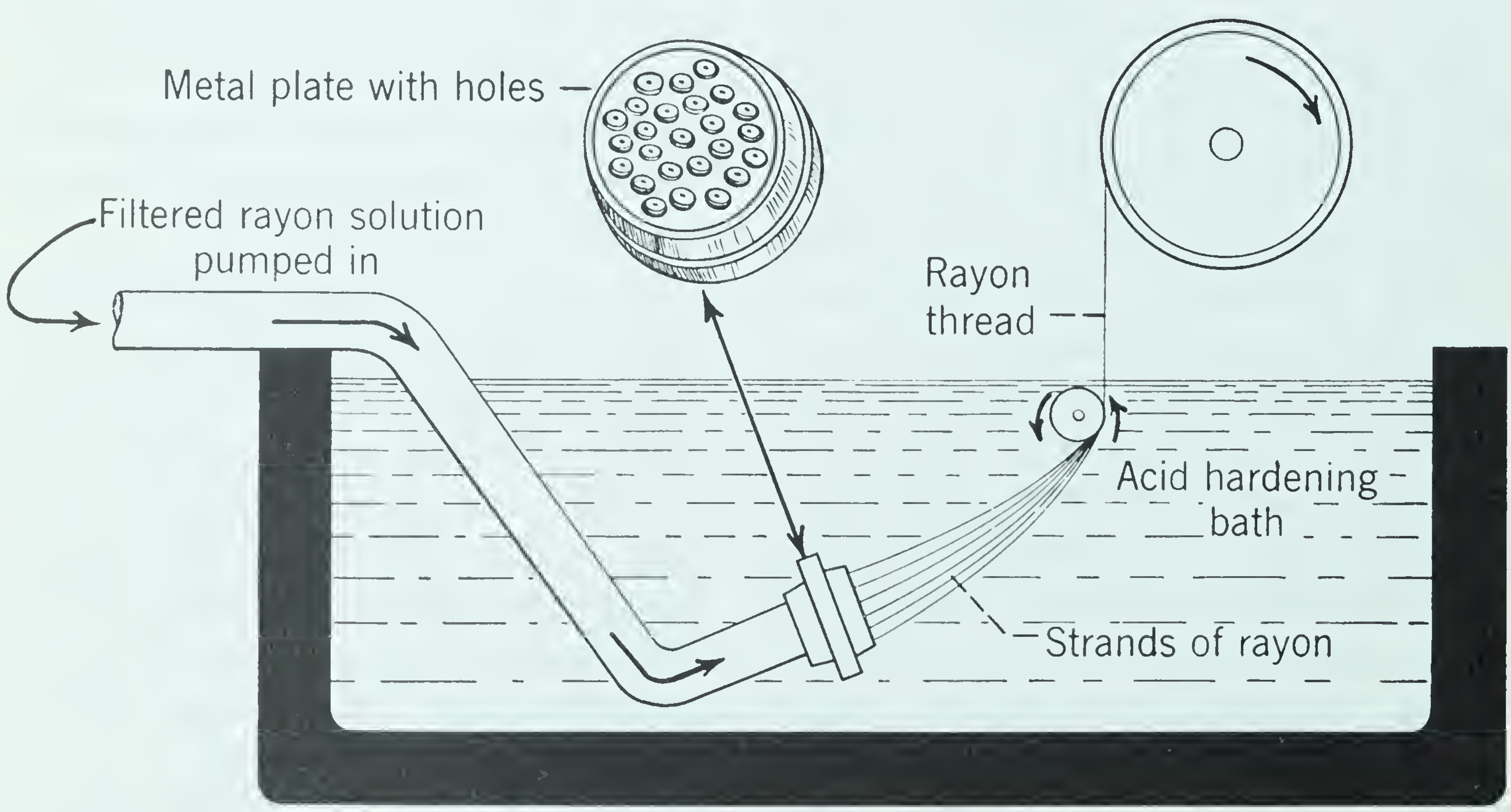


Fig. 15-24. The diagram shows you how rayon thread is made from a rayon solution.

Fig. 15-25. The photograph on the left shows a synthetic material, Neoprene. The machine shapes it into a solid. On the right is shown the beginning of the first completely synthetic fiber, the forerunner of nylon.

improved on the silkworm. The silkworm produces one tiny filament of silk at a time. Man uses a metal plate about the size of a dime that may have 100 holes. Thus we get 100 strands of the textile fiber at one time. By using thousands of these little metal plates in a rayon factory, we can produce tremendous quantities of textile fiber each day.

PUPIL ACTIVITY

Collect samples of trimmings of rayon, nylon, Dacron, and other new textile materials from the sewing room at your school. Or, you can find samples of these at home from old, discarded garments. Test little pieces of each of these textiles to see if they will burn. Boil a small piece of each of them in dilute hydrochloric acid, and then boil other pieces in dilute sodium hydroxide. Make a list of the properties of each of these materials that you observe.

You are familiar with rayon and nylon as two of these new kinds of textile fibers. There are a number of others, too, such as Vinyon, Velon, Saran, Orlon, and Dacron. Still other new textile fibers made by the chemist are coming on the market soon. They will be used for making shirts, suits, dresses, curtains, and awnings. Each will have certain properties that make it desirable for particular purposes. It is quite possible that in the near future synthetic textiles will replace natural ones for most purposes.

REVIEW QUESTIONS

1. What is the big fault with celluloid? **2.** What are the two main groups of plastics? **3.** What articles are made from Bakelite? **4.** What class of plastic is used for the windows in the front of an airplane? **5.** How do we make new textile fibers from some plastic materials?

QUESTIONS FOR REVIEW AND DISCUSSION

1. How do we know that ancient man knew some of the facts of chemistry? Can you list some chemical change with which he was familiar?
2. What event began the period of modern chemistry?
3. How would you decide whether an unfamiliar material was a metal or a non-metal?
4. Name the property that makes each material useful: copper for electrical wiring; coal in furnaces; aluminum in aircraft frames. Is the property involved physical or chemical? Why?
5. In what ways is the structure of an atom similar to our solar system?
6. Has man actually created new elements that do not occur in nature?
7. What is the relationship of the following to each other: molecule, atom, electron, proton, neutron?
8. Why did chemists find it necessary to choose a standard for relative atomic weight? Why was oxygen chosen? What weight was assigned to the oxygen atom?
9. Why do the elements silver and iron have symbols that do not begin with the first letter of their names?
10. How do we distinguish between a symbol, a formula, and an equation? Give one example of each.
11. What is the advantage of a structural formula?
12. What must be known before you can write a chemical equation?
13. Which scientific law requires that an equation be balanced? State this law.
14. If a farmer's land is too acid, how can he correct the trouble?
15. Why do we not use hydrochloric acid as the acid substance in baking powder?
16. Why would yellow laundry soap be unsuitable for shampooing your hair?
17. What is used to make glass for fine table glassware?

SPECIAL REPORTS AND PROBLEMS

1. The discovery of oxygen by Priestley.
2. Sketches showing the arrangement of electrons, protons and neutrons in the first ten elements.
3. The purification of crude rock salt for use as table salt.
4. The development of chemical symbol writing from the time of the alchemists to the present.
5. How glass is made and shaped to form milk bottles.
6. The materials used and the method of making rayon.

TESTING THE PURPOSES OF THIS UNIT

1. Define or give the meaning of each of the following words or terms:

   element, compound, mixture, metal, nonmetal, molecule, atom, electron, proton, neutron, nucleus of atom, atomic weight, symbol, formula, radical, acid, base, salt, neutralization, effervesce. thermoplastic, thermosetting.

2. Classify as element, compound, or mixture:

   lemonade, lead, baking soda, copper, calcium carbonate, stew.

3. How do we decide whether a substance is an element or a compound?
4. How do we distinguish between a compound and a mixture?
5. How does the molecule of an element differ from the molecule of a compound?
6. What unit of matter is represented by a symbol? By a formula?
7. How do we account for this: Fe is the symbol, and also the formula, for iron?
8. What information do we get from the formula for table sugar, $C_{12}H_{22}O_{11}$?
9. Write a formula with no radical in it. Write one with one radical in it. Write another with two radicals in it.
10. Which represents a radical: Na or OH? Give the reason for your choice.
11. Which contains the higher percentage of iron, red iron oxide, Fe_2O_3, or magnetic iron oxide, Fe_3O_4?
12. What is the name of the compound composed of (a) potassium and chlorine, (b) magnesium and bromine, (c) zinc and oxygen? What is the ending of the last word in each case? Write the formula for each.

13. Write structural formulas for: H_2S, $PbCl_2$, CuO, NH_3? What is the combining number of each element in each formula?

14. Write formulas for: sulfuric acid, calcium hydroxide, oxygen, tin. How many atoms are in each formula?

15. Write formulas for the two chlorides of mercury. Name each compound.

16. Give an illustration of a chemical change brought about by: (a) the action of bacteria, (b) heating, (c) contact, i.e. by two reactants touching each other, (d) light.

17. In terms of molecules how does a physical change differ from a chemical change?

18. Write equations for these chemical changes:

(a) The neutralization of hydrochloric acid by calcium hydroxide
(b) Heating limestone
(c) Slaking quicklime
(d) Action of sulfuric acid on limestone

19. What procedure would we follow to show that a piece of rock contained a carbonate?

20. Why do we store acids in glass bottles rather than in metal containers?

21. Why must we store quicklime in air-tight containers?

22. Why has the term *salt* acquired a broader meaning to you as a result of the study of this unit?

23. What is the general composition of all baking powders?

24. How is Pyrex glass different from other kinds?

25. What was the first modern plastic and how is it produced? Why have other plastics become more popular?

26. What are the advantages of new textile fibers over the old natural fibers? Have these new fibers any disadvantages?

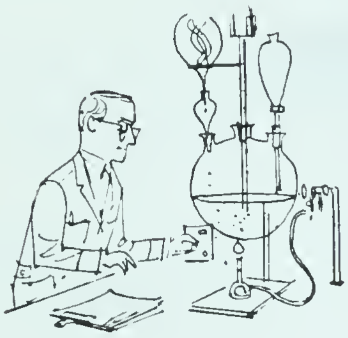
27. What is the one way in which all *salts* are alike?

The old

ANCIENT MAN MADE GLASS, POTTERY, DYES, AND SOME OTHER things, but he did not understand chemistry. He worked by "rule of thumb." The directions were often handed down from father to son and only scanty instructions were written. When something went wrong, man usually blamed the moon for the failure. He was still very superstitious.

The new

TODAY SCIENTISTS MAKE CAREFUL RECORDS OF THEIR EXperiments. They publish the details so others can repeat the tests to confirm them. With the introduction of the balance by Lavoisier, chemistry changed from a "rule of thumb" process to real science.

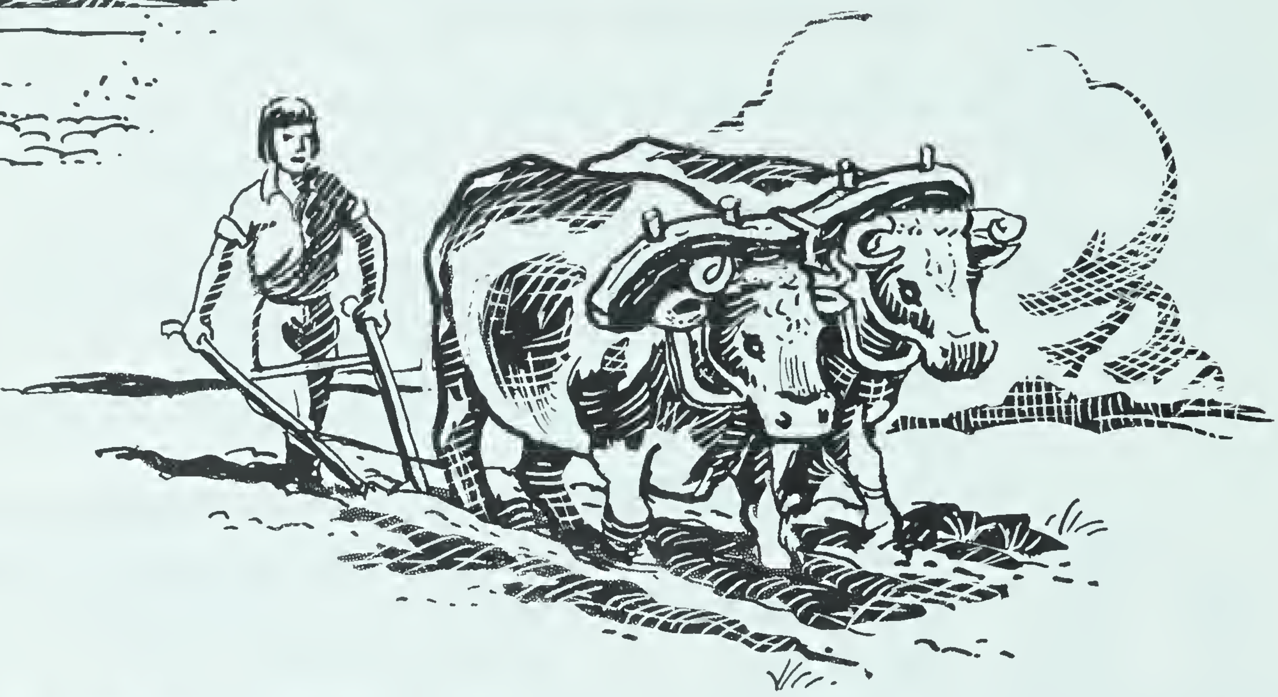


Instead of trying to get rich by changing lead into gold, chemists now try to find all the facts about a substance in the hope that they will discover something that everyone can use and enjoy.

Many men and women are studying science today. With so many people working, the secrets and mysteries of chemistry are being revealed. We read about some new chemical discovery almost every week.

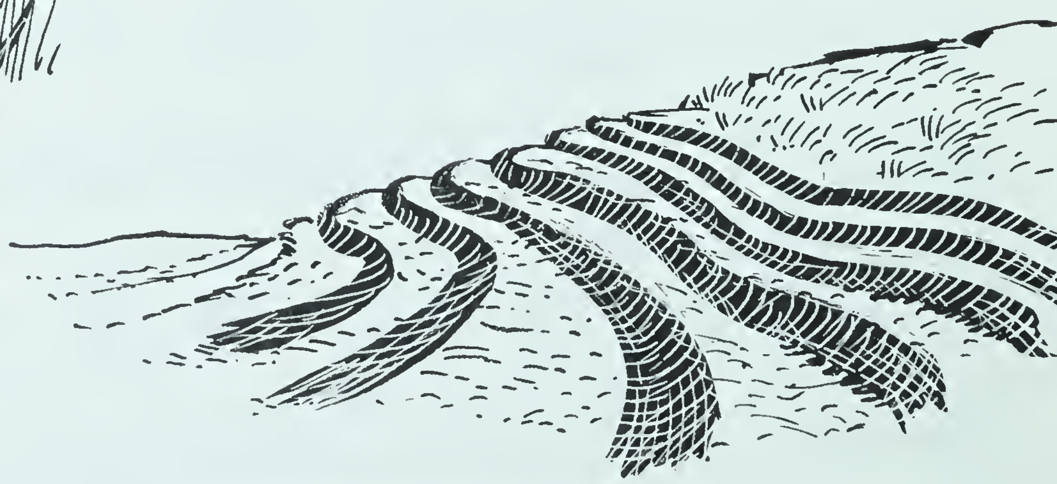
No doubt chemists will continue to make new products that will be better than those being used at present. There is great need for better and improved methods of making foods, fibers, metals, chemicals, and plastics. The rapid increase in population makes it necessary to develop many new products if everybody is to be well-fed and well-clothed.

Probably the greatest achievement of man in the last decade was the splitting of the atom. So important is this discovery that it has been likened to the advance man made when he learned how to use fire. Each of these advances, the use of fire and the splitting of the atom, represents steps forward in man's understanding. He must now put his knowledge of atomic energy to beneficial uses which will make our world a more enjoyable place in which to live.

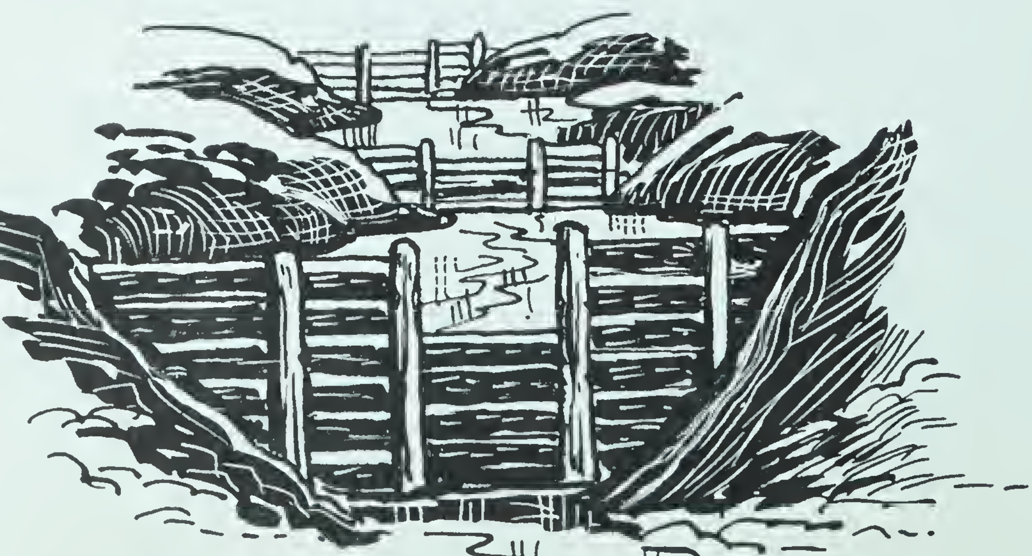


Early Methods of Planting
and Cultivating

Gully Erosion



Terraced Hillside



Check Dam

UNIT 16

DISCOVERY AND PROGRESS

How has man learned to use the soil and keep it fertile?

THE earth has not always been as it is now. The earth's surface, its rocks, and the plants and animals living on it have changed very slowly. The history of these slow changes has been written by the remains of those living things preserved in the rocks. These remains are known as *fossils*.

It is believed that the earth was a mass of molten lava and gas when it was formed. As the outer surface cooled, it shrank. As it shrank, mountains, plains, and valleys were gradually formed. Water vapors, also cooling, became water and filled the valleys making lakes and rivers. Large areas of the earth's surface filled up with water and became oceans which covered most of the earth.

During the millions of years following, the rocks of the earth's surface have been broken up in various ways: by oxidation; by cool rains that have cracked the hot rocks; by running water and waves; and by winds blowing fine particles about. Huge masses of ice, called *glaciers* (*glay*-shers), moved over parts of the earth, crushing, grinding, and carrying masses of rock great distances. We can see some of these changes in various parts of the earth today.

The earliest forms of life were probably tiny one-celled plants which lived in water or on ice. As these tiny plants became stronger, they were able to help break down bits of rock which became food for the plants which followed. This long struggle for existence was carried on for millions of years before higher plants and animals could live on earth.

Early man was a hunter, roaming about seeking food. Later, he learned the value of fruits and seeds as food. He found that if he stirred the soil and took out weed plants, the food-producing plants would grow better. Then he found he could plant seeds and establish a place for his food plants to grow. Thus, he did not need to roam the country to find food.

Later, as man tamed animals for his own use, women began to devote their time to the home, the children, and the animals. Daily hunting was not necessary and the men took on most of the hard work of farming.

The first plow was probably nothing more than a stick scratching the surface of the soil. As the stick became better shaped for the purpose, and new materials and tools came into existence, it developed into the plow. Man originally did all the work himself. Later he trained his animals to help him. At the time of the discovery of America, the plow was still a clumsy wooden tool. Later, machinery and metal tools came into use. Gardeners in southern France were among the first to plant their crops in rows and use horse-drawn cultivators. Jethro Tull, an Englishman who observed this practice, introduced it into England. Since that time a host of men have contributed to the invention and development of a wide range of agricultural equipment and power machinery. The large teams of combine harvesters are examples of this progress.

As time went on, man learned that certain crop plants would improve the soil if he cut them down and plowed them under. He discovered that the best ones were peas, beans, clover, and alfalfa. These same plants, together with certain grasses, are used today by farmers for plowing under to improve the soil. We call them green manure.

Either directly or indirectly, all human food comes from the soil. It is not surprising, then, that from the earliest times man has tried to discover how plants change the mineral matter of the soil and the gases of the air into living matter, which in turn becomes food for animals. The successful farmer of today is concerned with many problems. He must choose crops wisely, preserve soil fertility, prevent erosion, destroy insects, and control plant diseases.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. How were some of the rocks of the earth's crust formed? **2.** What are fossils and what is their importance? **3.** How are soils formed? **4.** What are the different kinds of soil? **5.** How do farmers prevent erosion in their fields? **6.** How may moisture be kept in the soil? **7.** Why should we conserve our forests? **8.** Why do plants grow better in cultivated soils? **9.** What is an acid soil? **10.** What is humus?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

eartnquake . . . . the result of the movement or tremor of the earth's crust.

erosion . . . . the carrying away of soil and rocks by wind, running water, or glaciers.

fossils . . . . impressions of, or permanently hardened remains of, plants and animals of the past, preserved in the earth's crust.

glacier . . . . (*glay*-sher), a huge mass of ice and snow formed in mountains and often moving slowly down into valleys.

humus . . . . (*hew*-mus), the decayed and decaying parts of animals and plants in the soil.

igneous rock . . . . (*ig*-nee-us), rock which has been formed by the cooling of hot, liquid material from the interior of the earth.

metamorphic rock . . . . (met-ah-*mor*-fick), rock which has been changed under great pressure and heat.

nitrogen-fixing bacteria bacteria living in nodules on the roots of leguminous plants which have the ability of changing gaseous nitrogen of the air into soluble salts of nitrogen.

sedimentary rock . . . . . rock formed from mud, sand, and gravel which have been carried by water in prehistoric times and deposited in layers.

weathering of rocks . . . the changing of rocks into soil by means of chemical and physical changes.

A How are rocks formed?

The lighter rocks are on the outer surface of the earth. Man has actually gone down into the earth for about 1½ miles. There are some mines that are that deep. As you go down into the earth, the temperature gets hotter by about one Fahrenheit degree for each 55 feet, or about 100° for the first mile.

The increased pressure of many miles of rocks keeps the rocks at the center of the earth from melting. The pressure makes the rocks plastic. Slowly, the heavier rocks and materials are pulled toward the center of the earth by the force of gravity. Thus, the center of the earth contains the most dense materials. The lighter rocks are pushed toward the outer surface of the earth.

The contraction of materials at the center of the earth makes the material smaller. Then the outer crust sometimes forms great cracks on its surface. *Earthquakes* are the result of the movement of the earth's crust.

Fig. 16-1. This photograph of the Bromo volcano in Indonesia shows the cone with the hot lava at the base.

Fig. 16-2. These layers consist of sedimentary rock, one of the three classes of rocks. They were formed by the hardening of pebbles, sand, and mud on lake or sea bottom in past geological ages. These materials were carried into the lake or sea by ancient rivers which eventually deposited them on the bottom. New layers covered old layers and the bottom was gradually built up. The whole process may have taken many thousands of years.

The crack formed by the rocks sliding up or down, or breaking apart, is called a *fault*. In the earthquake in San Francisco, California, in 1906, there was a crack in the earth 20 feet wide.

Sometimes hot, liquid rock material, called *lava*, flows out through the great cracks, builds up mountains, and continues to flow over the land for many miles. If water should flow down through these cracks until it meets hot rocks, steam under pressure will be produced. The enormous pressure of this steam, together with other gases, causes a break in the earth's surface and a volcano is formed. Large quantities of gases, dust, and melted rocks continue to flow from the opening in the earth. Gradually, the melted rocks cool, and a hard surface results.

Changes on the earth's surface have been very slow. Scientists estimate that the earth is over three billion years old. The many changes which have occurred on earth have been so slow that no one can see them, except during earthquakes, when volcanoes erupt, or during violent storms.

Coal has been found in the Parry Islands, but the climate and plants found there today could not possibly form coal now no matter how much time there was. But the presence of coal there tells us of past events and the changes which have taken place.

Parts of the earth that are land now were once below the level of the sea. Other parts of the earth which were land are now under the sea. Some lakes have disappeared, and others are gradually becoming smaller and smaller. Some rivers have vanished and others formed. These changes are brought about gradually by sun, wind, water,

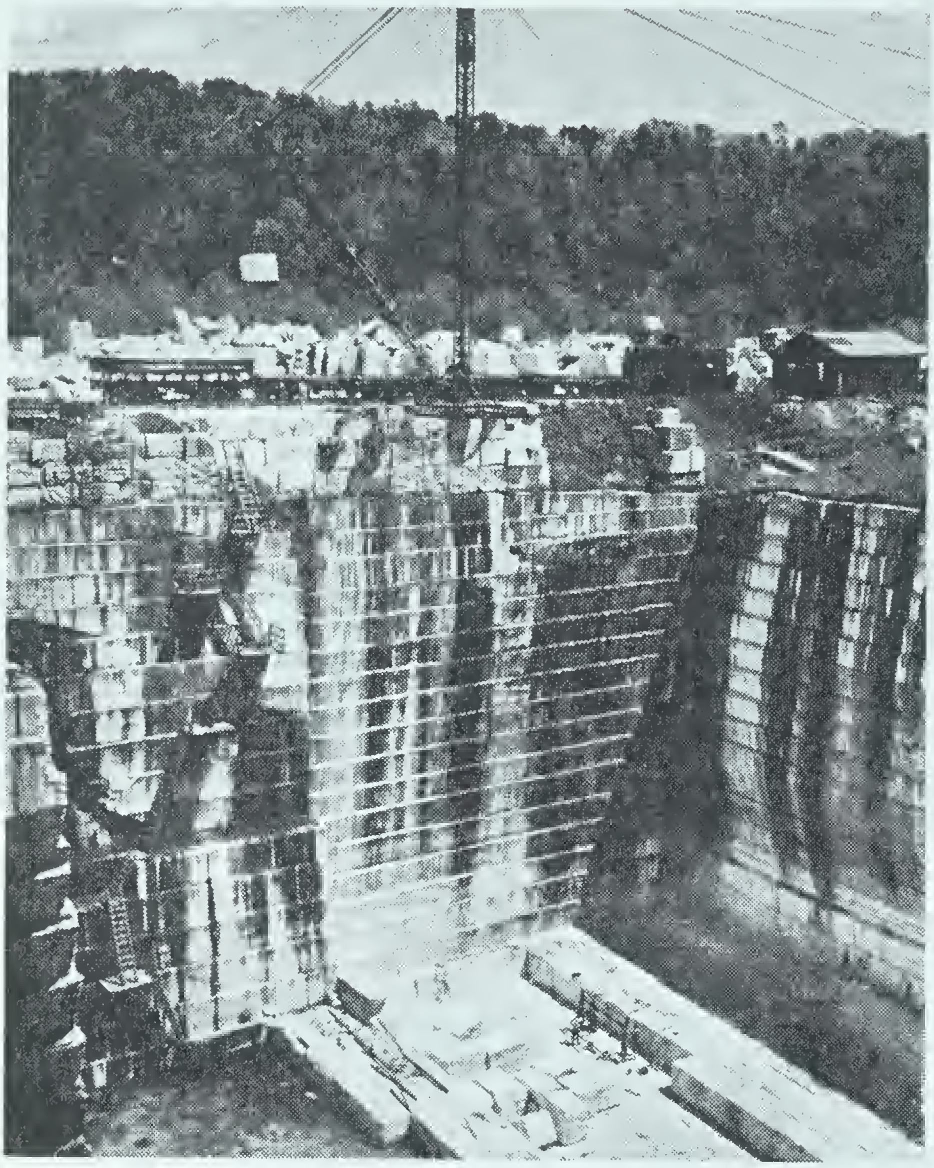


Fig. 16-3. This interesting marble quarry is located in Georgia. Marble is an example of metamorphic rock.

gravity, man, and chemical processes.

There are three classes of rocks. Those formed by the cooling of hot, liquid material are *igneous* (*ig*-nee-us) *rocks.* Many of our igneous rocks have resulted from the eruption of volcanoes.

Sedimentary rocks are those which have been deposited by water. Mud, sand, and gravel, carried by ancient rivers, have become hard and dry. They are formed in layers which have gradually hardened and the result is what we know as *sandstone* and *shale.* Sandstone comes from sand, and shale from mud. *Limestone* is produced by the shells of tiny animals living in the

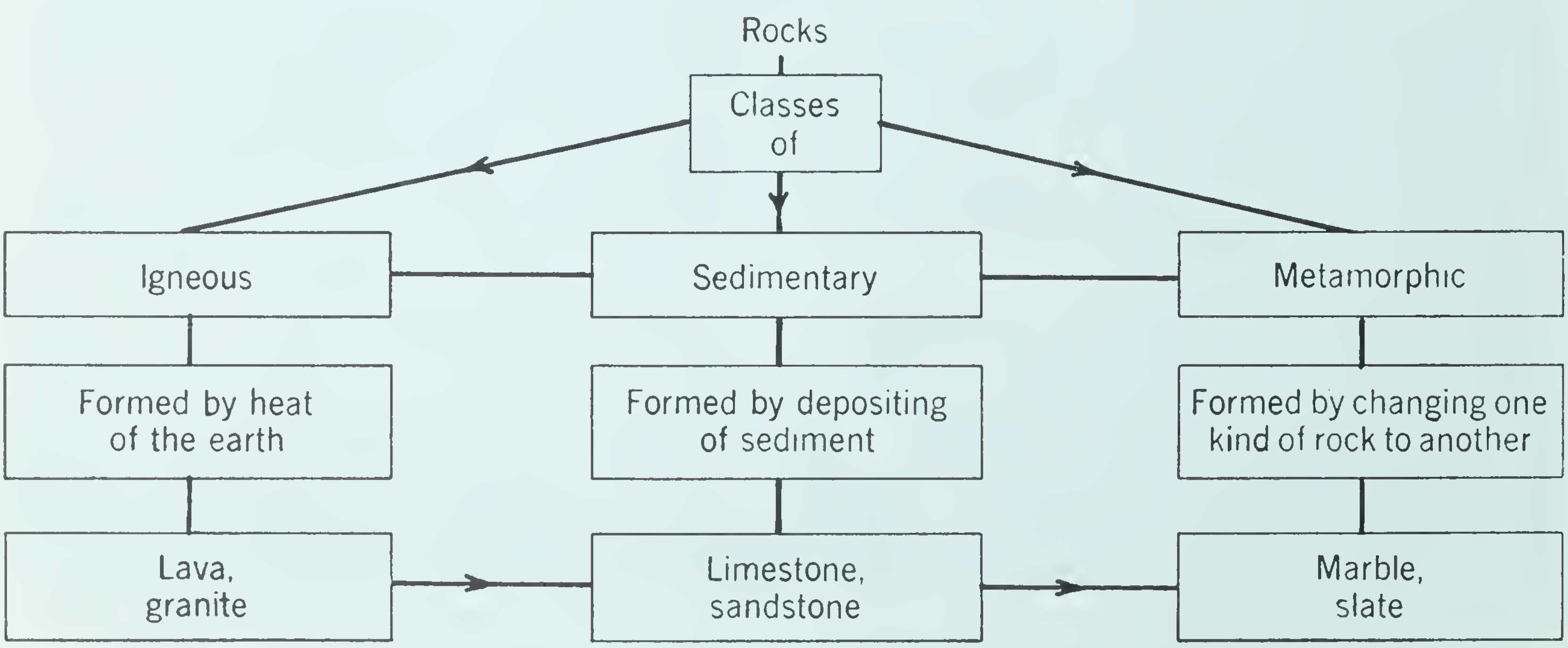


Fig. 16-4. This chart gives a summary of the classes of rocks and their formation.

bottom of lakes or seas. There are millions of these and when the animals die, their shells are ground up by waves to form deep layers.

We might call ***metamorphic*** (met-ah-*mor*-fick) ***rocks,*** "changed rocks" because they have been formed from other rocks under great pressure.

Marble is a good example of a metamorphic rock. It comes from limestone. Millions of years ago the limestone was heated under the pressure of the earth's surface and changed into marble. Marble differs from ordinary limestone because in cooling it has crystallized.

DEMONSTRATION

Place a few drops of hydrochloric acid on a piece of limestone or marble. Try the same thing on some other common rocks. Results? What is the test for limestone? Make a collection of rocks and tell which contain limestone.

Hydrochloric acid forms bubbles of carbon dioxide gas when it acts on marble or limestone but not on other rocks. You can prove that the gas given off is carbon dioxide by testing it in limewater.

Fossils in rocks show the age of the rocks. In the layers of sedimentary rocks, formed millions of years ago,

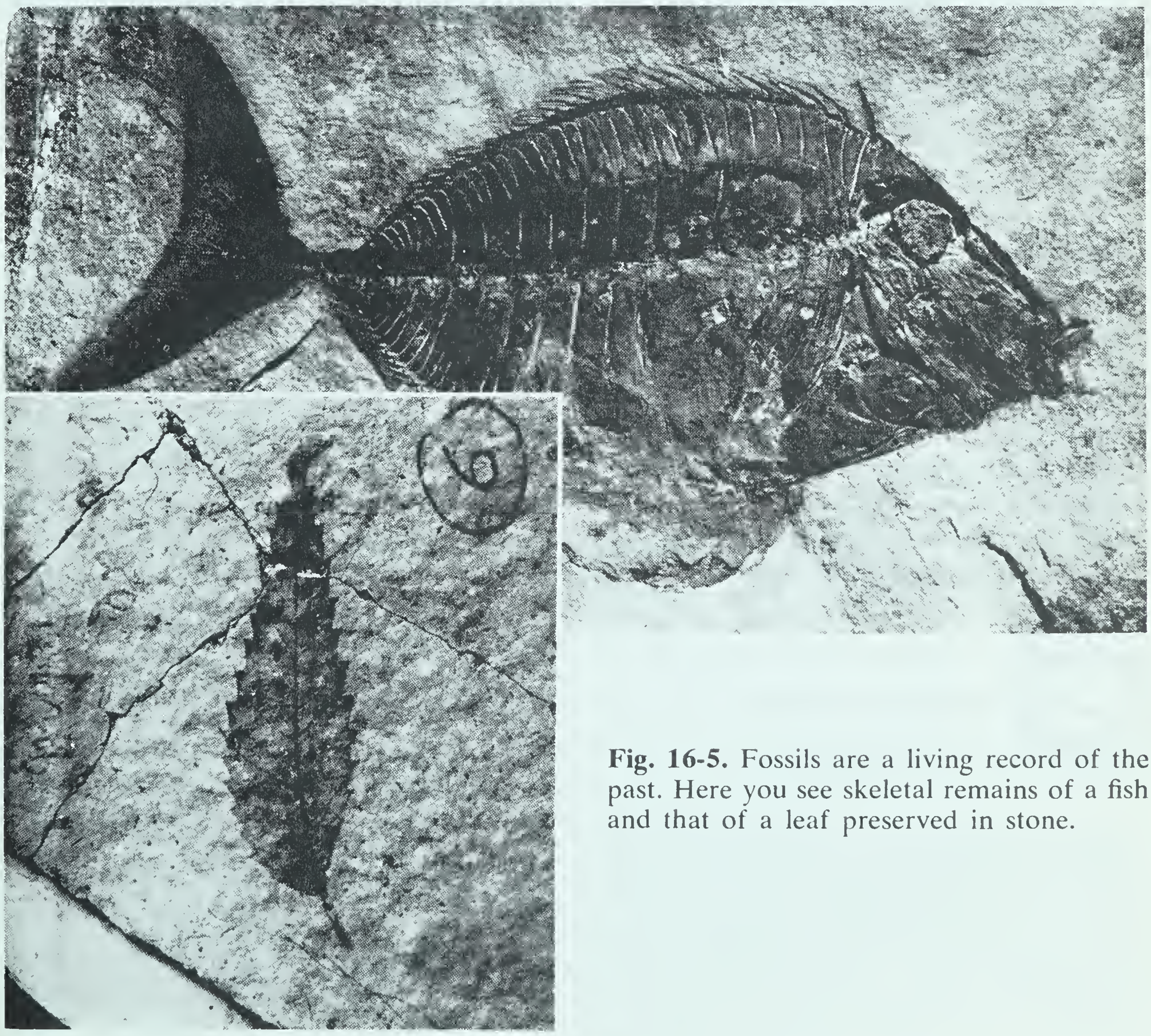


Fig. 16-5. Fossils are a living record of the past. Here you see skeletal remains of a fish and that of a leaf preserved in stone.

we find the fossil remains of prehistoric plants and animals. *Fossils* are impressions of, or permanently hardened remains of, living things of the past. These remains have been preserved in the earth's crust.

Fossils not only give an accurate record of the plant and animal life of the time, but also give us information about the age of the rocks and the length of time it took each layer to form. The lower layers contain the fossils of tiny plants and animals which are supposed to be the first forms of life. As you examine higher layers, you may see other fossils which are not so old. And the uppermost layers contain fossils of a still younger period.

REVIEW QUESTIONS

1. Why do we find the lighter rocks on the outer surface of the earth? **2.** What are the causes of earthquakes? **3.** What are the three classes of rocks? Give an example of each. **4.** How is each of the three classes of rock formed? **5.** How is marble formed and what is the test for it? **6.** What does the presence of fossils in rocks show? **7.** What is the cause of volcanoes?

B How are rocks changed to soil?

Soil consists of a mixture of rocks and decayed plant and animal matter. The *soil* is the outermost layer of the earth's crust and comes chiefly from rocks.

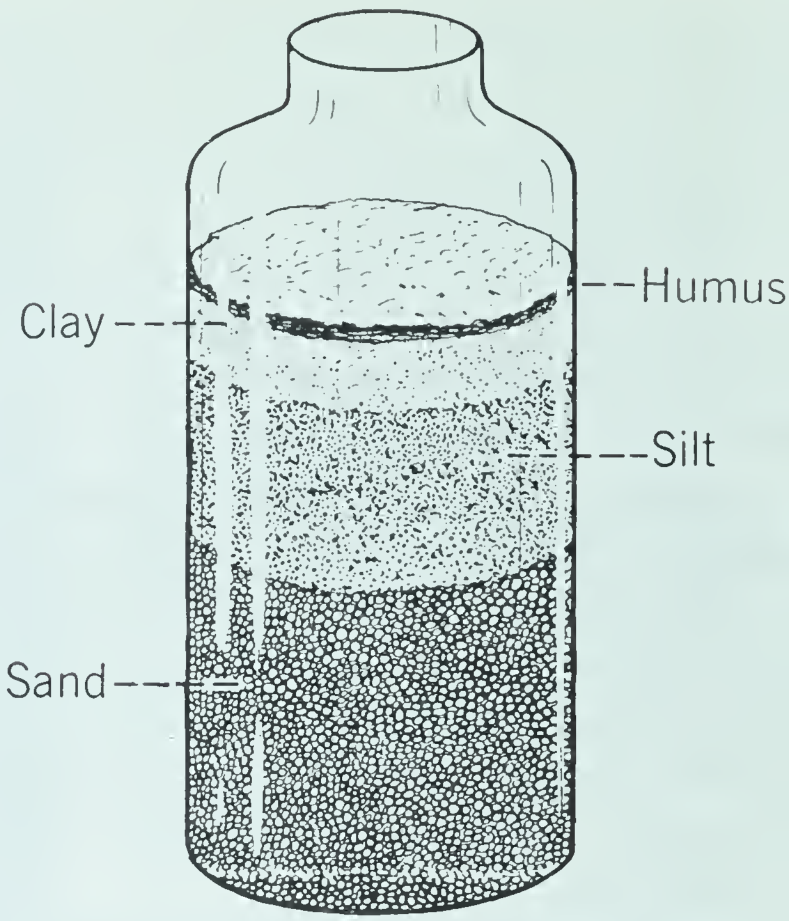


Fig. 16-6. When you mix soil with water and let it stand for several hours, the heavier particles will settle at the bottom.

PUPIL ACTIVITY

Put a handful of ordinary garden soil, or that found in flower pots, in a wide-mouthed bottle, such as an olive bottle. Fill the bottle with water. (Fig. 16-6.) Shake well and let it stand for a few hours. Result? What layer collects at the bottom? At the top? If these layers hardened, what would be formed?

Examine the different layers of soil or rock in some cut made through a mountain or hill. How were they formed?

The dark upper layer contains *humus* (*hew*-mus), the decaying remains of plants and animals. Because this is lighter it settles more slowly and therefore forms the upper layer.

The layer below the humus is *clay*. It is composed of the smallest and finest particles of inorganic matter. *Clay* is mostly decomposed *feldspar*, which is a part of granite rock. In a piece of granite, the glassy particles

Fig. 16-7. The action of waves beating against a cliff is severe enough to cause weathering of the rocks.

are *quartz*. The parts that break up into more or less rectangular pieces are feldspar, while the paperlike pieces are *mica* (*my*-kah).

Below the clay layer in the bottle there is a layer of *silt*. Particles of silt are not quite so small as particles of clay. *Silt* is largely oxidized rock and forms slate when it hardens.

Below the silt layer is a layer of sand whose particles are larger than those of either clay or silt. In some soil, you may even find a lowermost layer of *gravel*, although this is rare in garden soils. In this case, the particles are largest of all.

So you see, most soil contains particles of several different rocks mixed with organic matter.

Weathering is the changing of rocks to soil by physical and chemical action. Water seeps into the cracks in the rocks and between them. It increases in volume when it freezes and causes the rocks to break apart. Gradually the broken pieces become smaller and smaller. The force of gravity pulls them to lower levels and the crashing of rocks against each other wears off some of the sharp edges. After a long time, the rock is ground up into small pieces.

Temperature changes cause the rocks to expand and contract. If these changes are rapid, those rocks on the edges of cliffs will crack and fall off. If cold rainwater comes in contact with the heated rocks, the rapid contraction will make them break apart. Or, in the hot sunshine the outer edges only may expand and fall off. This continual expansion and contraction of rocks over

thousands of years breaks up large rocks into smaller ones. The smaller ones finally become even smaller and smaller until they form soil particles.

DEMONSTRATION

Fill a glass bottle with water and cork it. Leave it outdoors when the temperature is below freezing, or put it in the freezer of a refrigerator. Result? What happens when water is frozen in cracks in rocks? Why are there piles of rocks at the foot of a rocky cliff after the spring thaws?

Pour cold water on a piece of hot glass. Result? What may happen to hot rocks when cold rains suddenly strike them?

Observe the stones or bricks in walls. Are small particles crumbling away? What is happening to them? Do they seem to be slowly changing?

Rocks are also ground into finer pieces by running water, by ice flows, and by winds. Rivers cause the smaller rocks to roll against each other and over each other. This wears off the edges gradually. The running water also causes the rocks to roll along the ground. This makes them round and smooth. Gradually, and over thousands of years, the rocks are ground smaller and smaller and eventually become gravel and then sand.

The sand thus formed may be deposited on the banks of a river and then carried by wind. Wind which carries much sand can wear away the edges of soft rocks. This is especially true where winds strike cliffs and other exposed rock surfaces.

Chemical changes cause rocks to break up into soil particles. Ground

Fig. 16-8. Running water, if unchecked, can cause gully erosion such as this one.

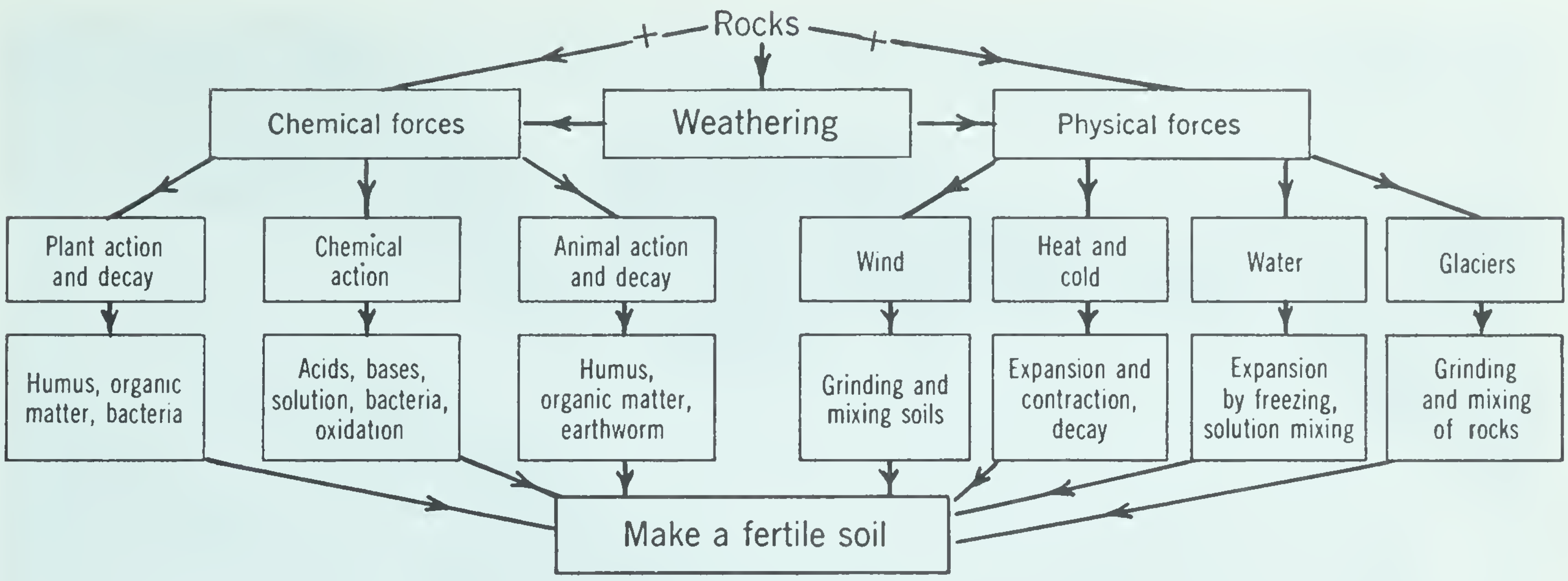


Fig. 16-9. This summary chart shows the process by which soil is formed from rocks.

water contains carbon dioxide, as well as the compounds set free by the roots of plants and the decay of living things. It causes various chemical changes to take place. These changes slowly cause the rocks to break apart. In some cases new chemical compounds are formed. The remains of plants and animals are decomposed and become mixed with the soil particles. The chemical action between the decayed materials and the small soil particles continues until fine soil particles are formed.

Limestone, which is largely calcium carbonate, is changed to a soluble form when water containing dissolved carbon dioxide passes over it. This change in limestone explains the formation of the large natural caves in Tennessee, Virginia, Kentucky, and other areas.

Fig. 16-10. Dust storms carry away quantities of valuable soil and deposit it in distant places.

Fig. 16-11. As this glacier moves slowly down the mountain it carries loose rocks and stones into the lake.

Erosion is the carrying away of soil by wind, running water, and glaciers. Running water is constantly wearing away soil and carrying it into the sea. The soil often forms deltas at the mouths of large rivers, as in the case of the Mississippi. This river carries many millions of cubic feet of soil into the sea every year. Its delta increases in length about one mile each 15 years and is already about 200 miles long. Another famous delta is at the mouth of the Nile River in Egypt.

River deltas have fertile soil because the water carries the rich topsoil from upstream and deposits it in the delta.

Dust storms carry away much valuable soil. The most serious storms occur in areas where there is loose soil without many plants growing in it. The winds blow strongly, pick up the soil, carry it hundreds of miles, and then deposit it at another place. This not only exposes poorer soil, but also covers up crops and good soil wherever the dust settles.

Winds form sand dunes near the beaches. Here, the dunes will consist largely of loose sand which is blown by winds from the lake or ocean. They constantly shift according to the winds, and get larger or smaller. The soil in dunes is not fertile because it has practically no organic matter in it.

Glaciers cause erosion in mountain regions. *Glaciers* (*glay*-shers) are huge sheets of ice and snow formed in mountains. More snow falls in winter

than can melt in summer. The water and snow, pressing on the snow underneath, produce enough pressure to melt some of the snow. The same principle occurs when you make a snowball by squeezing the snow in your hands. The pressure melts some of the snow. When you release the pressure, the melted snow freezes again.

These large moving glaciers have force enough to wear away hills and to carry them into lower valleys. They carry loose rocks with them and wear off the sharp edges. The glaciers fill up river beds and make valleys and lakes. When they reach an area of higher temperatures, they melt. Then the rocks and soils they have been carrying are deposited. Such deposits are a mixture of rocks, gravel, and sand.

REVIEW QUESTIONS

1. What is weathering? **2.** What are the agents of weathering? **3.** How may a change in temperature cause rocks to crack? **4.** How do living things help to change rocks into soil? **5.** How are soils formed? **6.** What is erosion? **7.** What is a delta? **8.** How are glaciers formed? **9.** How do they change rocks into soils?

C How can soil erosion be prevented?

Running water is the main cause of erosion. Perhaps you have noticed that steep slopes have small rills and gullies on them if they are not protected by plants. These are formed because swiftly moving water carries more soil and, therefore, cuts a deeper path than slowly moving water.

Some of the water flowing down a slope sinks into the soil and softens it. Thus running water not only carries soil with it, but also makes the soil ready for more erosion.

The loss of soil by erosion results in a serious decrease in agricultural productivity. Rainwater carries untold millions of tons of soil into rivers and streams each year. It cuts gullies, rushes down hillsides, and sweeps over slopes of cultivated land. With this lost soil goes many million pounds of valuable minerals used by plants for food-making.

PUPIL ACTIVITY

Examine, if possible, a hillside that is covered with trees, another covered with grass, another cleared and under cultivation. From which will the rainfall run off most quickly? From which will it carry the most soil? Explain why. Try to find places where farmers are preventing erosion in their fields. How is the dirt held? Is the method successful?

Soil erosion is prevented by decreasing the speed of running water. In many gullies we can put logs, rocks, and even shrubs at regular distances apart. These all help to slow down the flow of water because they act like small dams. Little ponds form back of these dams and the flow of water is slowed. Soil gradually fills the ponds and eventually makes level areas which can be planted with trees or shrubs. The gully is then filled in and no further erosion will occur.

Fig. 16-12. Due to improper methods of soil conservation, this field has been badly eroded during a heavy rain. How might this have been prevented?

Farmers use many ways to prevent erosion in their fields. One way is to plow around hills instead of up and down. This is called *contour farming.* If you plow up and down a hill, the furrows between each row are good places for little gullies to form. But if you plow around the hills, each furrow acts as a tiny dam to check the flow of water.

Another way is by *strip cropping.* Here, the farmer plants grain or grasses in narrow strips. Then he plants a different crop, like corn or cotton, in the next strip. The strips follow the contour of the ground around a hill or valley. Erosion is prevented in two ways: (1) the flow of water is slowed; and (2) the roots of the plants help to hold the soil in position.

On sloping land, farmers often build *terraces* almost like a flight of stairs. A small ditch at the back of each terrace holds the water and keeps it from running down on the next terrace.

Roots of plants hold the soil. Hillsides covered with plants seldom erode. Trees, especially, are useful in holding back water from heavy rains. Their roots hold the soil in place, and humus collects under them. This acts like a sponge in holding water in the soil.

Wind is also an important cause of erosion. Some sections of the prairie provinces have suffered from serious dust storms. These have carried soil as far east as Toronto and Montreal at times and sometimes even farther. The rich topsoil has been removed and fields which used to be rich have been stripped of the best part of the soil. This means a heavy loss to the farmer.

Fig. 16-13. Here are contour strips on a slope. A four year rotation of corn, wheat, and grass is being practiced.

One way to prevent serious damage from these strong winds is to plant rows of trees at right angles to the direction of the wind. These are called *shelter-belts.* The trees act as windbreaks by slowing down the speed of the wind. They also prevent heavy evaporation of water from the soil, and are a satisfactory way of stopping wind erosion.

Another way to conserve the soil from wind erosion is to plant *cover crops.* These remain on the land during the winter and keep the soil from blowing away. They not only keep the

Fig. 16-14. Terracing is a type of contour farming used on steep hillsides to prevent erosion.

soil on the field, but also serve as food for livestock during the winter months.

REVIEW QUESTIONS

1. What is erosion? **2.** In what ways does flowing water cause erosion? **3.** How do strip cropping and terracing help prevent erosion? **4.** How do trees and grasses prevent erosion?

D What is fertile soil?

Fertile soil contains both inorganic and organic matter. Soils are formed from solid rock by the processes of weathering and erosion. Soils from rock alone, however, are not fertile because they need humus.

The top layer of soil is called the *topsoil.* A few inches of it requires many years to form. The soil below the topsoil is the *subsoil,* and may be many feet thick. Under the subsoil is solid rock.

Soils differ in properties and characteristics. The various kinds of soil depend on the proportions of the materials that compose them.

PUPIL ACTIVITY

Get samples of soil from your own yard or from some nearby open space. Fill a can or fruit jar with each sample. Keep them tightly closed until tested. Make a record of the following examinations of each soil.

What is the color of each? Is it dark or light? Rub a pinch between your thumb and finger. Is it coarse or fine? Squeeze a handful of the moist soil. If a crumbly ball is formed, it is mostly clay. Heat a shallow layer of the sample in a pan over a hot flame. Does the soil, after drying out, smoke or blacken? Blackening indicates humus.

The best soil is composed of three important materials: (1) *sand* for looseness; (2) *clay* for mineral elements; and (3) *humus* for waterholding power and fertility.

DEMONSTRATION

Fill a quart can with soil. Pack it so as to resemble natural conditions. Pour in a measured amount of water from time to time. Let stand until the soil is saturated with water. Results? What comes out as the water goes in? How much of your sample was air? How do roots get air?

Soil is a mixture of decayed rocks, such as limestone, sand, clay, gravel, and humus. There is water in the soil and also a considerable amount of air.

In addition, soil contains millions of

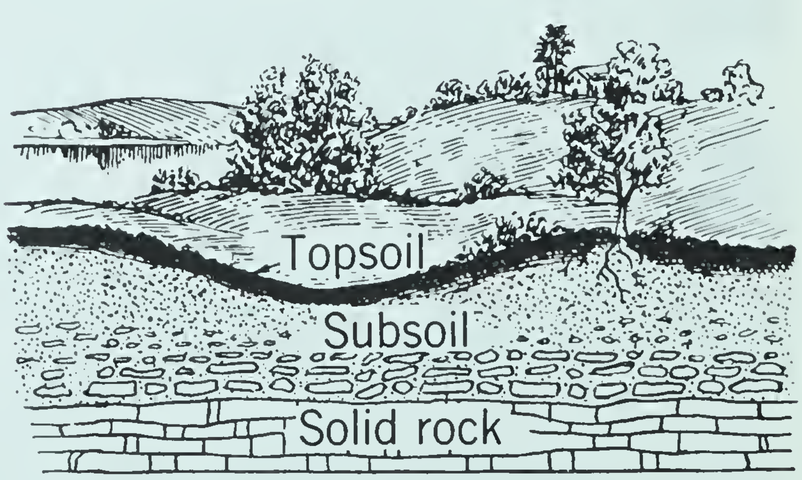


Fig. 16-15. The layer of solid rock is usually covered by a layer of subsoil and a layer of topsoil.

tiny living organisms such as bacteria and molds, as well as earthworms and other small animals.

A silt loam is probably the best soil. It contains all the materials needed for plant growth, enough sand to make it loose, and enough humus to hold moisture.

A soil changes in composition with the crops grown. The crops grown on poor soil never have the same percentage of chemical elements as those on good soil. Poor soils lower the quality and quantity of food grown per acre. To be sure of good crops each year, you must add fertilizer so the crops will contain the highest amount possible of each chemical element.

Minerals in the soil are used by plants for growth. Plants get calcium, iodine, iron, magnesium, boron, nitrogen, phosphorus, potassium, sulfur, and small amounts of other elements from the soil. These occur in combination in soluble nitrates, sulfates, and phosphates. Plants use nitrogen, phosphorus, and potassium in larger amounts than the other soil minerals.

This mineral matter in soil is made soluble by water, by the work of acids from humus, and by acids given off by roots. Where lime (calcium) is lacking, the soil is acid or sour.

DEMONSTRATION

Put a piece of blue litmus paper in a hole in moist soil a few inches deep. Observe after several hours. Result? If the blue litmus turns red, it means that the soil is sour, or contains an excess of acids.

If the soil is sour, put some of it in a saucer and mix it with about one-fifth the same amount of lime or wood ashes. Test the mixture with blue and red litmus. Result? If neither changes color, the soil is neutral. If the red litmus turns blue, the mixture is not acid, but alkaline. This condition is not harmful.

If the soil in your garden is acid, how can you correct it?

Marsh lands and other lands containing considerable decayed matter and water tend to become acid. The decay forms carbon dioxide and some other gases, which form weak acids with water. These acid soils are treated with lime or ground limestone. Since the lime is alkaline, it neutralizes the acid.

The scientific farmer also avoids loss of minerals in the soil by practicing crop rotation.

Soils containing humus hold the most moisture. The greater the amount of humus in the soil, the more water it can hold. Therefore, it does not dry up so readily in hot weather.

Sandy soil with little humus dries out quickly. Keeping your garden well supplied with humus is one of the best ways of caring for the soil.

REVIEW QUESTIONS

1. How is soil formed? **2.** What is humus? **3.** Name four kinds of soil. **4.** What is a fertile soil? **5.** What kind of soil will hold the most water? **6.** What is the composition of the best soil for gardens? **7.** What are the inorganic materials in soil? **8.** What is the organic material in soil? **9.** What is the test for acid soil? **10.** How do you neutralize acid soils? **11.** How does humus help conserve moisture in the soil?

E How can soils be kept fertile?

A soil is kept fertile by adding humus and minerals. Growing plants remove minerals from the soil rapidly. In time it loses nitrogen, potassium, and phosphorus.

When organic matter in the soil decays, it releases soluble compounds containing nitrogen and other needed elements. Humus is the universal remedy for poor soils. When quick results are needed, chemical fertilizers are added.

Humus can be made in a compost pile. Dig a hole about two feet deep and three or four feet square in an unused corner of your yard. Put grass clippings, leaves, weeds, vegetable parings, egg shells, and other plant wastes into the hole. Do this in layers and sprinkle a little lime on top of each layer. After adding the lime, sprinkle on a little garden soil. Let the material decay for at least a year, after which it should be rich, black humus. Then, it is ready to put on your garden.

Farmers cannot make large enough compost piles to supply their fields with the humus they need. They usually sow a cover crop and plow it under before planting. The green material decays fast and makes humus right in the field.

Soils should be tested to find what minerals should be added. Soils differ in their composition from time to time. Therefore, a soil test is necessary at least once a year. If any necessary minerals are lacking, they can be added by using a chemical fertilizer.

Chemical fertilizers have a label telling what per cent of nitrogen, potassium, and phosphorus is present in the mixture. Your soil test will show about how much of each your soil needs.

You can make your own test with a home kit which you can buy at most seed stores, or your provincial experiment station will gladly test it for you at little or no cost.

Soils may be kept fertile by crop rotation. Different crops remove the elements from the soil in different proportions. Nitrogen is the element most often removed, and if the same crop is grown year after year on the same soil, it will lose all its nitrogen. To prevent this, different crops are grown on the same land in different years. We call this ***crop rotation.***

Plants belonging to the pea family (peas, beans, clover, peanuts, alfalfa,

Fig. 16-16. One way of adding humus to the soil is by plowing under a green crop, such as sweet clover.

Fig. 16-17. Note the difference between these two crops. The plants on the left were grown without any fertilizer. Those on the right received a balanced fertilizer.

and lespedeza) are valuable crops for rotation. They have tiny nodules on their roots. These nodules each contain millions of bacteria called *nitrogen-fixing bacteria.* They have the ability to use the nitrogen gas in the air, and to change it into soluble salts of nitrogen. Since the soil contains a great deal of air, these bacteria do their work under the ground. These salts are soluble in water and can be used by the plant. Scientists believe that the gaseous nitrogen of the air is not used by any other living thing.

The soils in which *legume crops* (the beans and peas) grow contain an abundance of these nitrogen salts, and are therefore the best types of farm soils.

Soil water is conserved to keep soils fertile. Soil water is constantly rising to the earth's surface by *capillary* (*kap-ill-air-ee*) *action.* Water rises in blot-

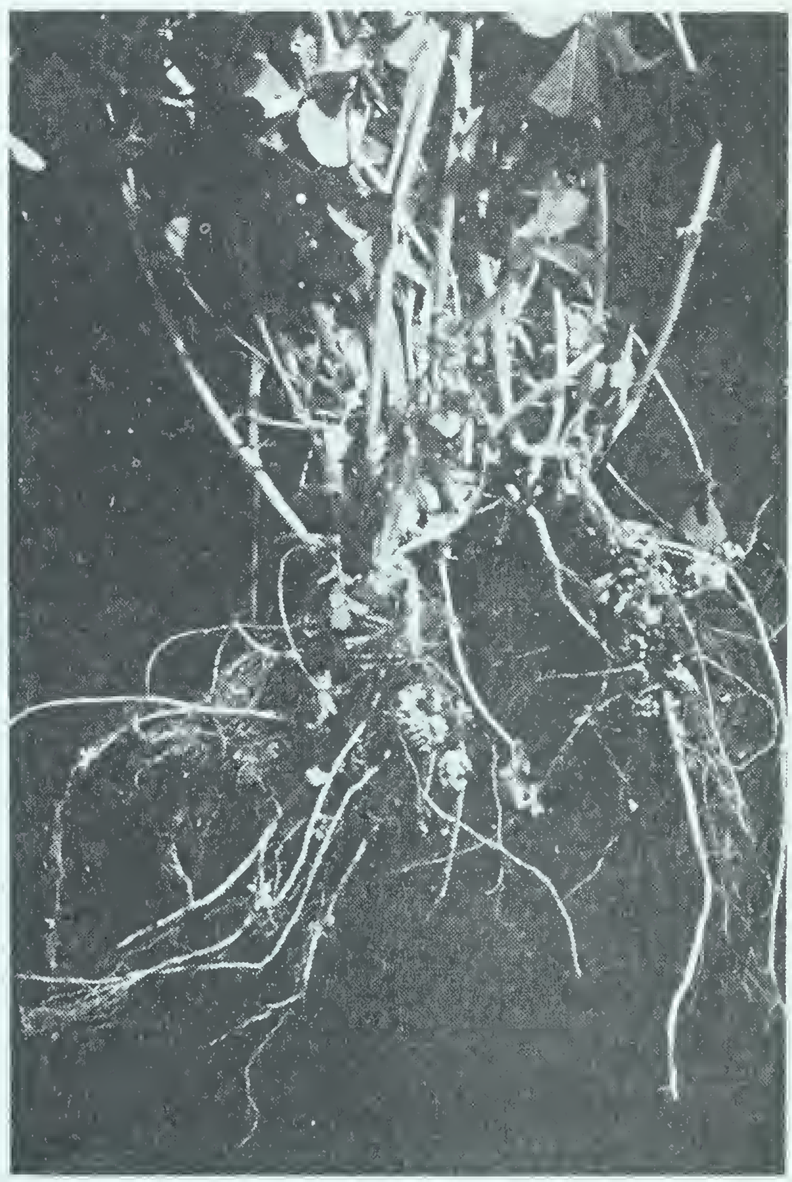


Fig. 16-18. Nitrogen-fixing bacteria grow in nodules on the roots of certain legume plants.

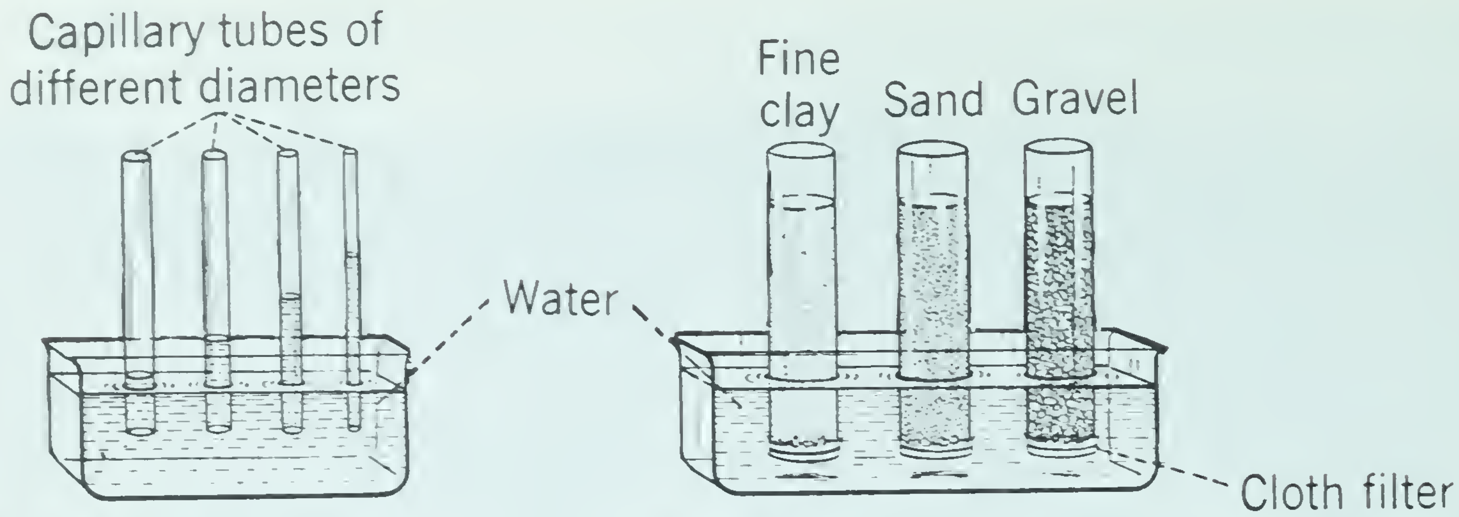


Fig. 16-19. The drawing on the left shows how capillary action is affected by the size of the tubes. Try the experiment on the right to show capillary action in soils. Which type of soil absorbs the most water?

ters and towels in the same way. The amount of water lost by evaporation at the surface of the soil in dry weather may be so great as to prevent plant growth.

The best remedy is to stir or till the soil often, and keep the top layer of two or three inches broken up to form a dust mulch. This procedure is known as *dry farming*, and is used in those regions where annual rainfall is low. You can also make a *mulch* with a covering of leaves, grass, or straw on any small area in your garden. The mulch tends to prevent soil water from passing up through the soil spaces to the surface.

DEMONSTRATION

Put a sugar cube in a shallow dish. Put some powdered sugar on top of the cube.

Fig. 16-20. The use of a mulch, such as straw, is one way of conserving soil moisture.

Cautiously add a few drops of colored water to the dish. Result? What represents the fine dust covering on stirred soil? What is a mulch? How could you make a dust mulch in your garden?

Get some capillary tubes of various diameters. Put them end down in a glass of water. What are the results? In which tube does the water rise highest? Conclusion?

Fill two boxes with soil. Plant pea seeds or young pea plants in both. Cover the soil in one box with sawdust or fine grass clippings. Do not mulch the other one. Set aside in a place favorable to growth and observe in a week or so. Results? What seems to be the effect of mulching? Is the soil under mulch more or less moist than the soil not under mulch? Why?

If a dust mulch becomes packed after a rain, wait until the soil is fairly dry, then crumble and cultivate it again with a fine rake.

A garden should be watered during dry weather. The best way is to use a hose and let it run for an hour or more. A light sprinkle does no good at all. It is better to water the garden thoroughly once a week and let the water sink deep into the soil than to do it lightly each day.

PUPIL ACTIVITY

Punch holes in the sides of old quart or gallon oil cans. Set them in the soil so that their rims are at a level with the surface of the ground in various places in your garden near plants that need water (see Fig. 16-21). Always keep the cans filled with water. Remove two or three inches of soil at a time near any of the cans and see if the water is seeping out sidewise and reaching the plant roots. Results?

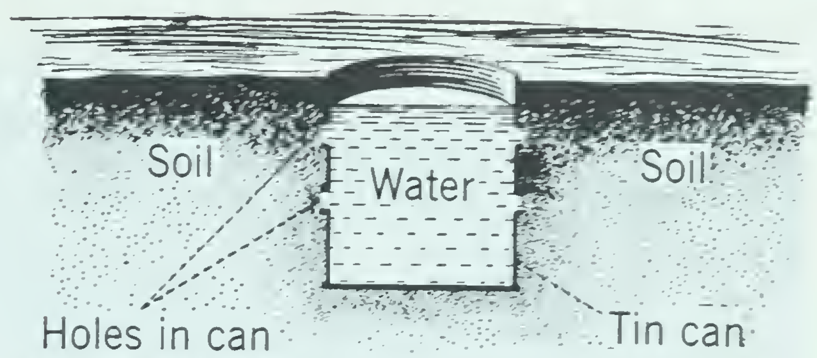


Fig. 16-21. Water passes from the sunken can to the soil by water pressure.

The water reaches the roots of the plants by capillary action. Roots are thus supplied with moisture for the plant.

Irrigation supplies water to dry regions. Dams are built in mountains or at high places. They store water during the winter and spring when rains are apt to be heavy. The water is then used in summer when it is needed. This is *irrigation* (ir-rih-*gay*-shun). See Fig. 16-22 on page 480.

The water reaches the areas to be irrigated by deep ditches through which it runs by the force of gravity. The flow is slow, and it runs from the large ditches into smaller ones, and finally into even smaller ones in the fields. Sometimes water has to be pumped to land areas above the ditches. In the fields it seeps out of the ditches and, by capillary action, reaches plant roots that are many feet away.

Large areas of the western provinces are now watered by irrigation. In addition, the federal government is co-operating with projects in the St. Mary, South Saskatchewan, Red Deer and Bow Rivers. These developments will affect hundreds of thousands of acres of farm land.

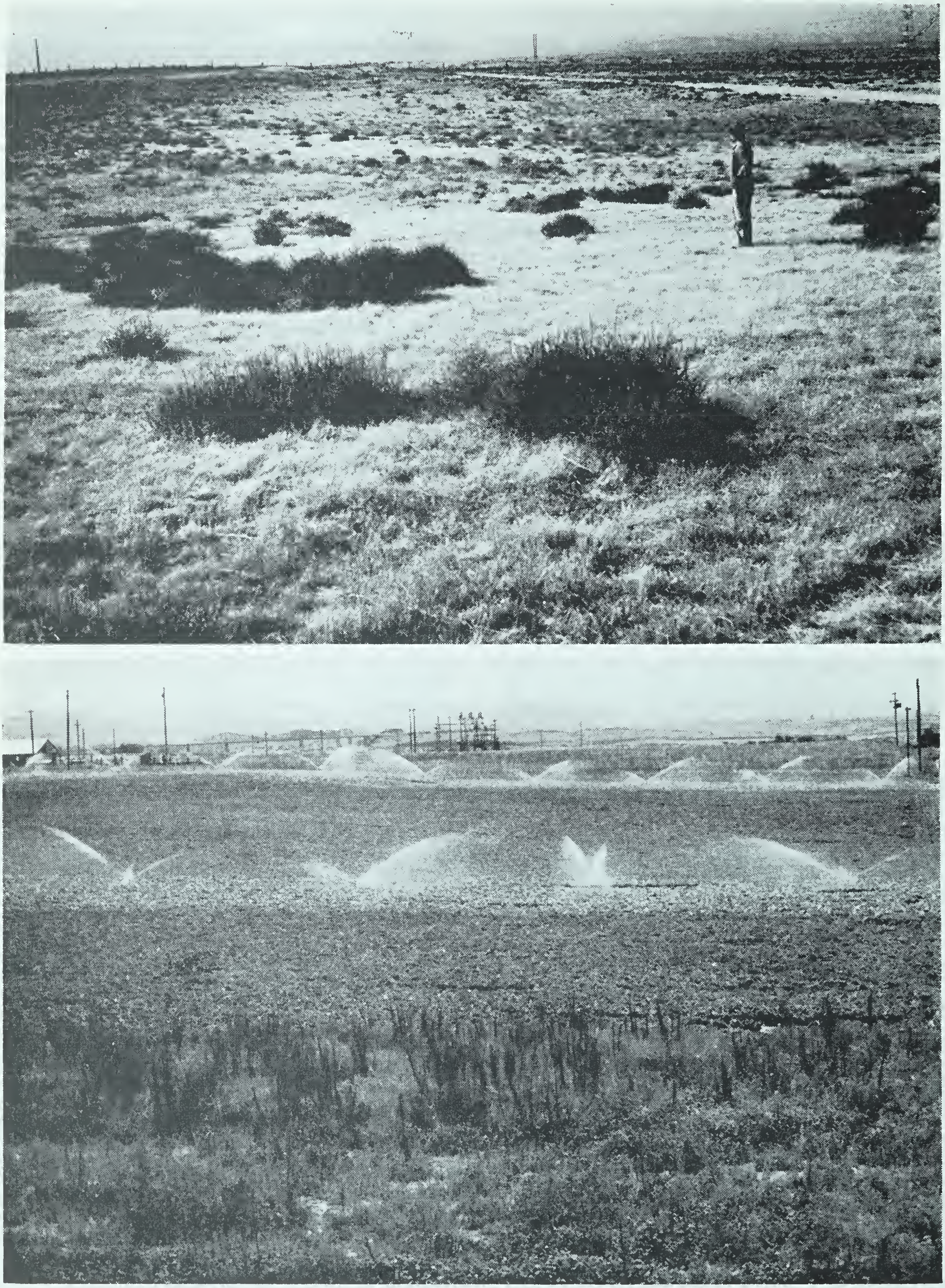


Fig. 16-22. In the top photograph, note the dry environment which is unsuited to agriculture. Below, the same area has been made useful for growing crops due to the bringing of water for irrigation.

REVIEW QUESTIONS

1. In what ways are minerals added to the soil? **2.** What is a compost pile and how do you make one? **3.** Why should you test soil before adding fertilizer? **4.** Why are plants of the bean and pea family important in crop rotation? **5.** How do nitrogen-fixing bacteria help the soil? **6.** What is a mulch? **7.** How does mulching your soil help prevent water loss through capillary action? **8.** How should you water your garden? **9.** How does irrigation help the farmer? **10.** In what areas is it most useful? **11.** What is dry farming? What are the conditions under which this kind of farming is practiced?

QUESTIONS FOR REVIEW AND DISCUSSION

1. In what three ways may rocks be formed?
2. What are the names of the three classes of rocks?
3. In what ways may rocks be changed into soil?
4. In which kind of rocks would you expect to find fossils?
5. Why do not all rocks contain fossil remains?
6. What is soil? How is it formed?
7. What are the various kinds of soil? What are the properties of each kind?
8. How does weathering break up rocks?
9. How do chemical changes cause rocks to break up into smaller pieces?
10. What is erosion?
11. In what ways may loss of soil by erosion be prevented?
12. What is strip cropping? How does it prevent erosion?
13. What is meant by terracing? How does it prevent erosion?
14. What methods can you suggest for the prevention of dust storms?
15. What materials does a fertile soil contain?
16. What methods should be used to improve the fertility of the soil?
17. What is the test for an acid soil? How can you correct soil acidity?
18. What minerals in soils do plants need for growth?
19. What kind of soil holds moisture best? What kind holds moisture least?
20. What effect does decreased soil fertility have on the crops which are grown on poor soil?
21. How do legume crops help in keeping soils fertile?
22. How does cultivation help to improve the soil?
23. What methods are used to conserve moisture during dry weather?
24. Under what conditions is it advisable to build large irrigation projects?
25. How is water distributed over soils by irrigation?

26. How does water seep through the soil?
27. Of what advantage is contour farming?
28. In what different ways is humus added to the soil?
29. What is capillary action? In what kind of soils does water rise the highest by capillary action?

SPECIAL REPORTS AND PROBLEMS

1. A plan for rotating crops in the home garden.
2. A plan for keeping the soil in my garden fertile.
3. How glaciers help make soil.
4. The section of my local museum which is devoted to a display of rock formations.
5. What is being done in my province to prevent soil erosion.

TESTING THE PURPOSES OF THIS UNIT

1. What is the definition of each of the following words or terms: rock, soil, fossil, erosion, weathering, irrigation, subsoil, topsoil, sedimentary rock, igneous rock, metamorphic rock, glacier, humus, strip cropping, cover crop, contour farming, capillary action, mulch, crop rotation, dry farming, soil minerals, nitrogen-fixing bacteria, conservation, shelterbelt?
2. In what ways may erosion by water and wind be helpful? Harmful?
3. In what ways is rock gradually being changed into soil? Are all these processes going on now the same as they did in years past?
4. Why is it becoming increasingly important to maintain the fertility of the soil?
5. Why do the federal and provincial governments develop conservation policies?
6. What methods are being used in your community to improve agricultural conditions?
7. What principles of science are applied in the federal government projects to control erosion?
8. What is an earthquake? How may it help in the formation of soil?
9. What is a volcano? In what ways may volcanoes be destructive? In what ways may they be helpful?
10. How have glaciers helped to improve soils? How might they help to produce poorer soils?
11. How do crops which produce large yields remove minerals from the soil as compared to crops of small yield?
12. How has the discovery of fossils helped in getting more knowledge of the earth's history?
13. Which kinds of rocks make the most desirable building materials?

The old

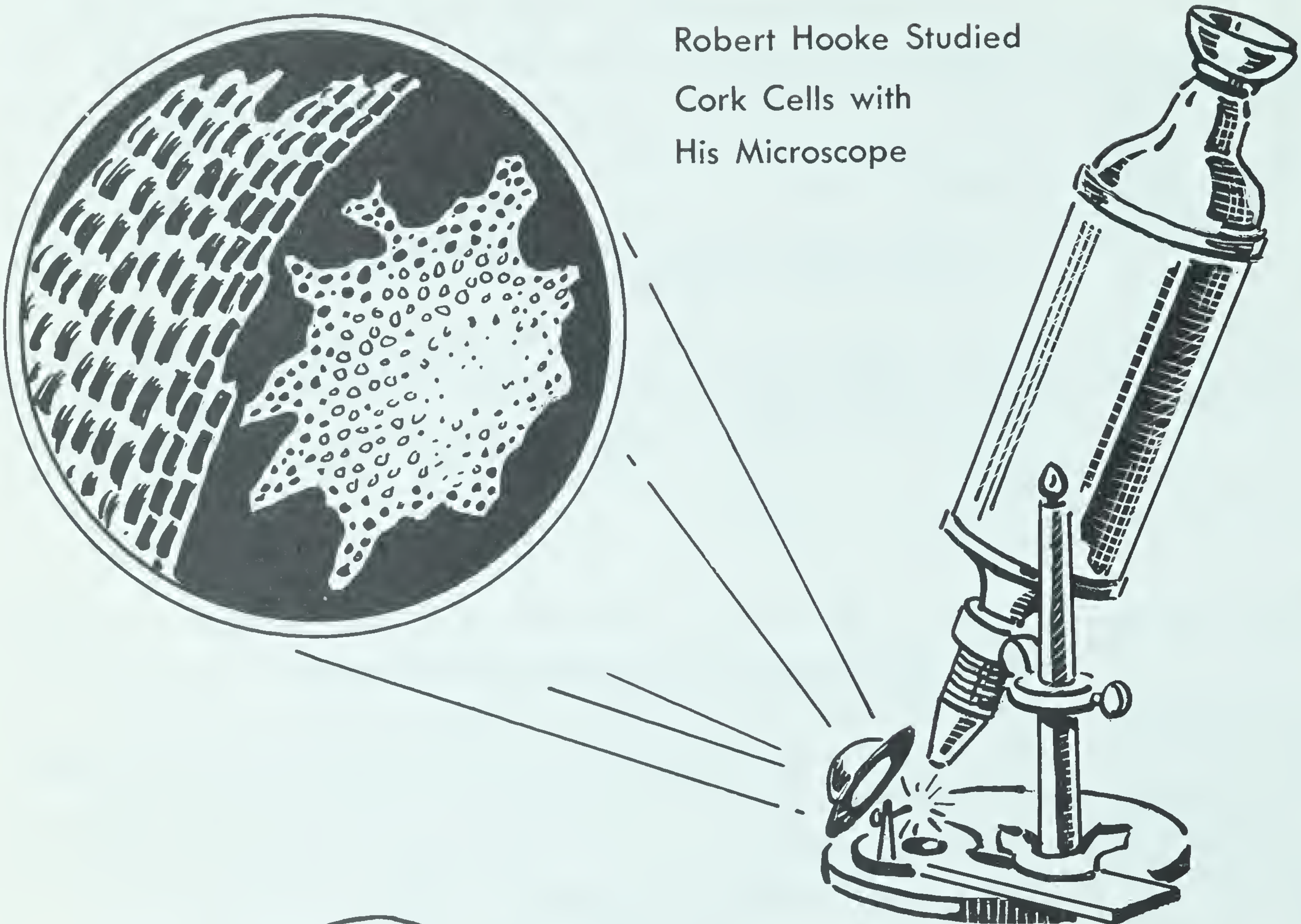
AGRICULTURE IS OUR OLDEST INDUSTRY. IN THE PAST, AS man found it necessary to produce his own food, he usually moved to places where he could get good land. As populations increased, it became more difficult to get good lands. This meant that poorer lands gradually became used for food production. Soon people living on such poor land found it difficult to earn a living. As more land was brought under cultivation people discovered that much of what they considered a gain was really a loss.

As long as man could get all the good land he wanted, he did not think much about maintaining the fertility of the soil. If his land would not produce good crops, he could go elsewhere.

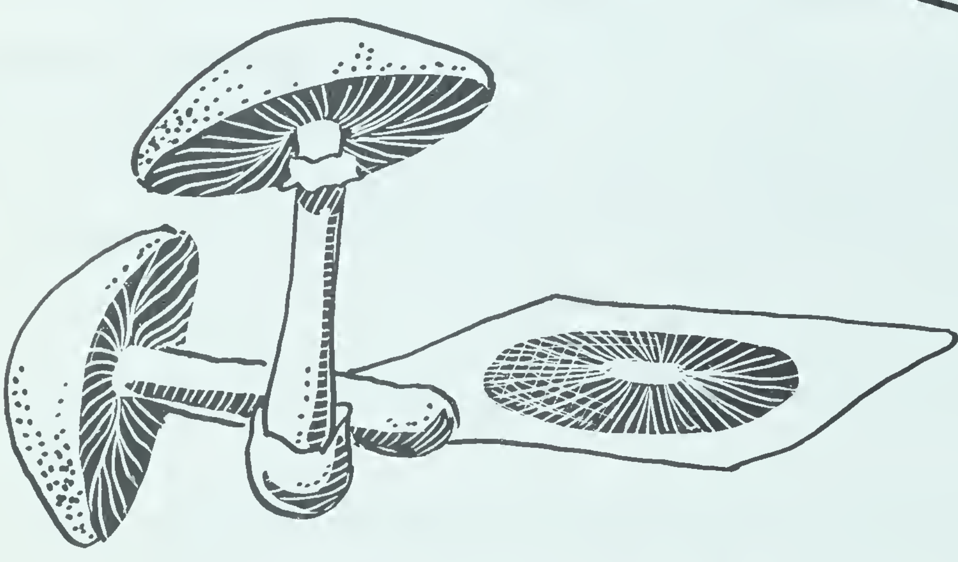
The new

TODAY IT IS QUITE A DIFFERENT STORY. WHEN A FARMER finds that his soil is no longer productive, he cannot pull up stakes and move on. Either he must use the soil as it is, or else improve the quality of the soil. He must test it regularly to be sure that it is not too acid, and to know what fertilizers to add. He must cultivate it to keep water in the soil, and must use mulches whenever possible.

Soil conservation is our most important problem in farming. It is our duty and privilege to keep it always at the highest level of fertility. Anything less than that will surely mean crops so low in food value that our health will be endangered.



Robert Hooke Studied
Cork Cells with
His Microscope



UNIT 17

How has man learned to grow plants and use them in daily life?

DISCOVERY AND PROGRESS

IN early times man did not know that plants come from seeds. Therefore, he did not know how to grow crops. He got his food by roaming from place to place, eating the berries and fruits that he found already growing. When he had eaten all the food in one place, he moved to a new source of supply. Then someone discovered that plants grow from seeds. Man learned to gather the seeds, to plant and harvest them. And when he learned that, he could stay in one place and grow his own food.

Ever since the discovery that plants grow from seeds, man has been interested in the growth of plants. The ancient Greeks knew that there were male and female date trees. Herodotus (he-*rod*-oh-tus), a Greek historian, wrote that if you dust a female date tree with the branches from a male tree, the tree will bear fruit. But no one tried to find out why this was so.

One day in the year 1667, an English botanist named Robert Hooke was using a crude microscope. In a thin slice of cork, he saw tiny boxlike structures, which he named *cells*. What he really saw was the dead cell wall. But he was the first to notice cell structure.

About 1687, Leeuwenhoek (*lay*-ven-hook) a Dutch scientist, made a better microscope than the one Robert Hooke used. He studied the nature of cells with it. He also saw tiny living things moving in a drop of stagnant water.

Then Malpighi (mal-*peeg*-hee), working in the 17th Century, found that raw food materials are carried through the stem of a plant to the leaves where the sunlight helped produce another change. He had a theory that the plant food is digested in the leaves and distributed through the plant. It was later proved that raw materials to make food in plants come not only from the soil, but also from the air.

Priestley, after discovering oxygen, noticed that green leaves give off oxygen in the sunlight. He also noticed that plants take in oxygen and give out carbon dioxide in the dark. A Frenchman, Saussure (sau-*sur*), verified Priestley's theory and proved that plants depend on such nonliving material as nitrogen and minerals in the soil as well.

In 1839, an important discovery was made by two German biologists. Schleiden, who studied animals, and Schwann, who studied plants, discovered that all living things are made of cells. But they went further than Hooke did. They proved: (1) that cells contained a living substance that made them different from nonliving things; and (2) that cells are the unit structure of all living things. In 1846 Von Mohl (*mole*), called this living substance *protoplasm*.

An Austrian monk, Gregor Mendel, showed why plants and animals are like their parents, though they will vary in some ways. This discovery started the branch of biology known as *genetics* (gen-*et*-icks), or the science of heredity. Scientists working with the laws of heredity can now breed plants and animals for special purposes, special soils, and special climates.

The first plow was probably nothing more than a stick scratching the surface of the soil. As the stick became better shaped for the purpose, and new materials and tools came into existence, it developed into the plow. Man originally did all the work himself. Later he trained his animals to help him. At the time of the discovery of America, the plow was still a clumsy wooden tool. Later, machinery and metal tools came into use.

Either directly or indirectly, all human food comes from the soil. It is not surprising, then, that from the earliest times man has tried to discover how plants change the mineral matter of the soil and the gases of the air into living matter, which in turn becomes food for animals. The successful farmer of today is concerned with many problems. He must choose crops wisely, preserve the fertility of the soil, prevent erosion, destroy insects, supply sufficient water, and try to control plant diseases.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. Why do we eat foods? **2.** Why do most plants grow so slowly in the shade? **3.** How do gardeners bleach celery stalks? **4.** What are seeds? Where are they produced? **5.** What are the various food nutrients? **6.** How do plants get mineral matter? **7.** What are the parts of a flower? **8.** What are fungi? **9.** What plant diseases are caused by fungi? **10.** How does the farmer protect his crops from plant diseases?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

carbohydrate . . (*kar*-boh-high-drate), any chemical compound such as sugar or starch, which contains carbon, hydrogen, and oxygen.

cell . . . . the unit of structure of all living things.

chlorophyll . . . (*kloh*-roh-fill), green coloring matter in cells.

digestion . . . . . the change of an insoluble food substance to a soluble form.

fungicide . . . . . (*fun*-ji-side), any substance that destroys fungi or inhibits the growth of the spores.

host . . . . any living organism or nonliving substance which acts as a source of food for another plant or animal.

mycelium . . . . (my-*see*-lee-um), the mass of thread-like filaments that makes up the main body of a fungus.

osmosis . . . . . . (os-*moh*-sis), the passing of liquids through membranes from a region of greater concentration to a region of lesser concentration.

photosynthesis . (foh-toe-*sin*-thih-sis), the manufacture of carbohydrate foods by the green cells of a plant in the presence of sunlight.

saprophyte . . . (*sap*-ro-fite), a plant that lives on dead organic materials.

tissue . . . . cells of the same kind grouped together.

Fig. 17-1. Machines for picking cotton have been invented. These make it possible to pick the cotton faster than by hand picking.

A What life activities do plants carry on?

The green plant is the source of all our food. You know that both plants and animals furnish us with food and other products. You probably do not realize, however, that if there were no green plants, you would have no food of any kind. Green plants are the great food factories of the world. You eat cheese, butter, milk, eggs, and meat that are furnished directly by animals. But these foods come indirectly from plants.

What are some of our valuable plants? The most valuable plant in the world is wheat. The second most valuable is the potato. The third is corn. Then follow oats, hay, cotton, and fruits in the order named. The cotton plant is a good example to show the variety of materials that we can get from one plant. Look at the table.

USES OF THE COTTON PLANT

Cotton Fibers	Cotton Seeds		
Wadding, absorbent cotton, felt, cellulose (paper, explosives, artificial silk), yarns (candle and lamp wicks, rope, twine, carpets), artificial leather, batting, stuffing (for cushions, pads, etc.), thread, cloth	Yellow Oil Lard compound Cooking oil Packing sardines Margarine	Cottonseed Oil Cosmetics Candles Lubricating oil Putty mixer Paints Tempering material	Soap Stock Soap Glycerol Dyestuffs

The green plant is a complete factory. All of us can recognize the four principal parts of a plant: (1) the *roots;* (2) the *stems;* (3) *leaves;* and (4) *flowers.* What is the work of each part? Do all work together or are they independent of each other?

The ***roots*** anchor the plant firmly in the ground and collect minerals and water. The ***stems*** help to hold up the plant and act as a delivery system between the roots and leaves. Food materials move up and down through the stems, and there some food is stored. Their strength is well-shown by the trunks of trees, bamboo poles, or cornstalks.

The ***leaves*** get energy from the sun and raw materials from the air, and they make most of the food. They also set free waste products. In addition, they take in oxygen and give off carbon dioxide. This latter process is called *respiration,* an activity common to plants and animals. During the food-making process they furnish to the air a fresh supply of oxygen to replace what animals use in respiration. The green leaf is the natural food-producing factory of the world.

The ***flower*** is the part which insures the continued existence of the species through reproduction. ***Fruits,*** which contain ***seeds,*** are produced by the flower. When planted, these seeds produce new plants. Enough food materials are stored in the seeds to keep the new plant growing until its own root and leaf systems are developed. Fruits and seeds are important sources of food for man.

The building and growing unit of living things is the cell. How does a builder build a house? By putting together bricks with mortar, or other materials. These are not alive, they

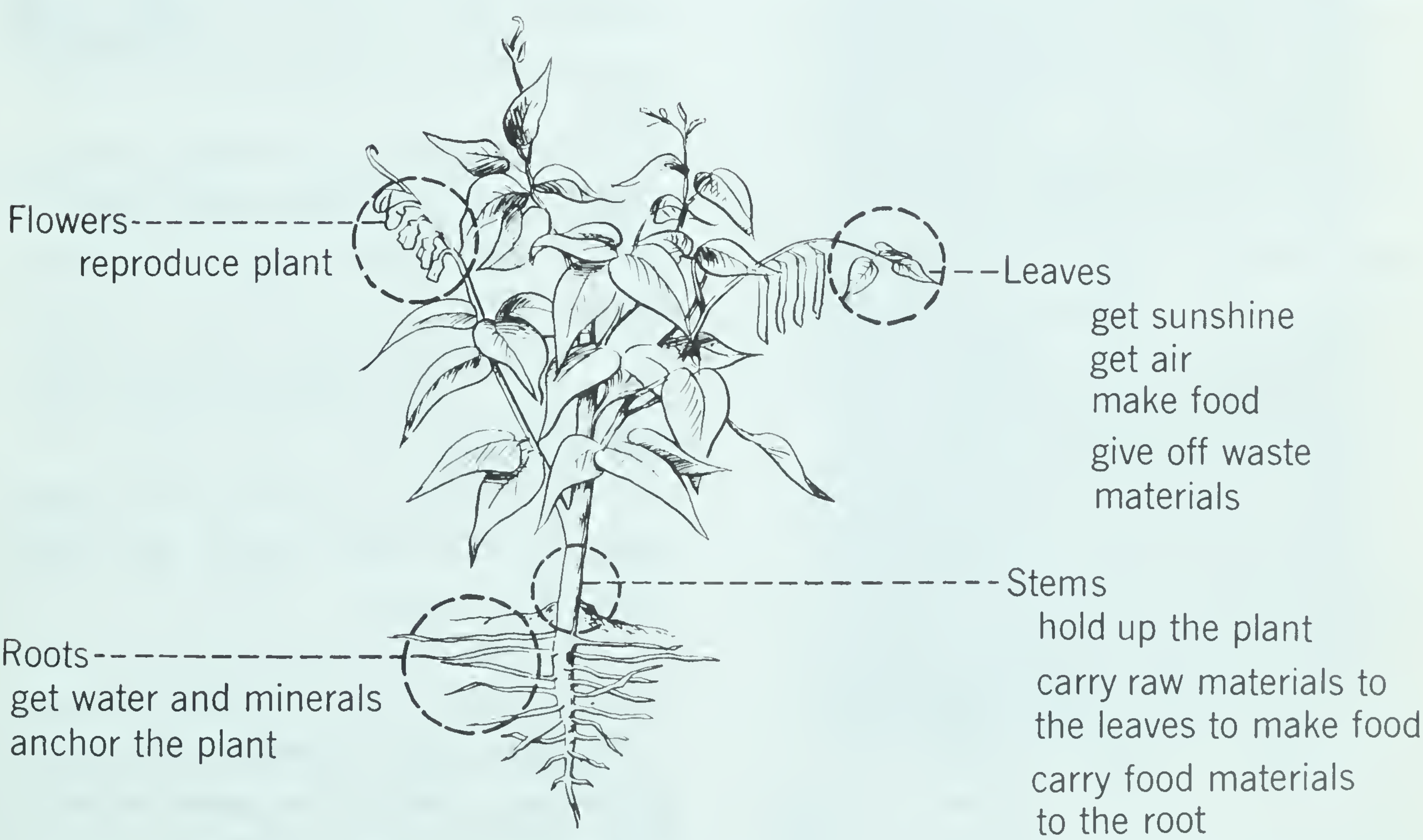


Fig. 17-2. The green plant is a complete factory in itself for producing food from raw materials.

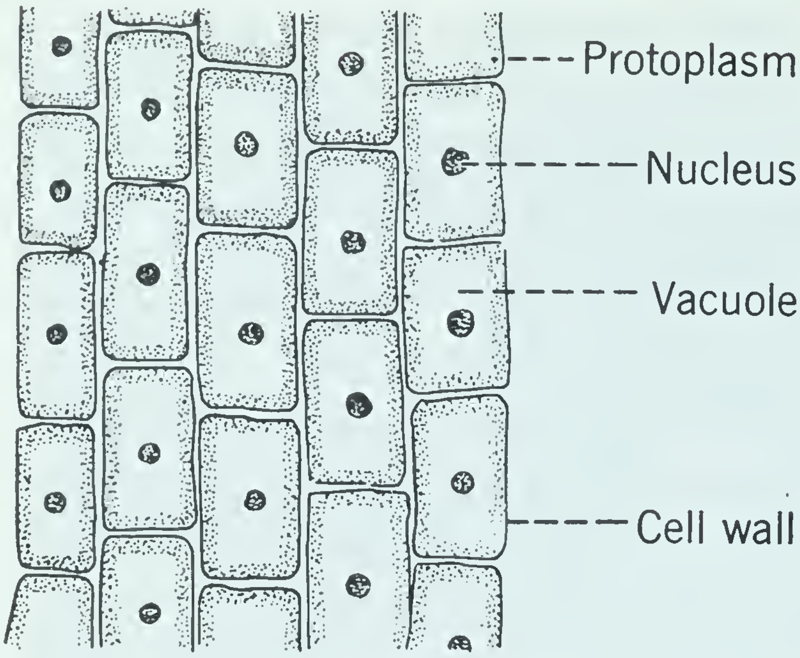


Fig. 17-3. This diagram shows the cells of an onion skin properly stained, as viewed under a microscope.

cannot grow, and they cannot move.

But the units of a plant are alive, and they can grow. These units are *cells,* and all plants are made up of cells. They are so small you can only see them with a microscope.

DEMONSTRATION

Get a very thin piece of onion skin. Stain it with iodine or methyl green. Put it under the microscope and make the necessary adjustments to get a clear view of the onion skin. Look for the cell walls, nuclei, and other parts you may observe. Are the cells united with one another? Do all of them have the same shape and the same size? Fig. 17-3 will help you to identify the parts.

Each cell consists of some protoplasm, part of which is formed into a *nucleus* (*new*-klee-us), and a *cell wall.* The nucleus appears as a spherical mass of protoplasm. Spaces in the protoplasm, called *vacuoles* (*vack*-yew-ohles), contain *cell sap,* which is composed of sugars, salts, and other materials dissolved in water.

Cells are usually grouped together. We call such groups of similar cells *tissues.* When tissues are grouped together, *organs* are formed. Organs may be made up of several kinds of tissues. Some plant organs are the root, stem, leaf, or flower. An organ such as your hand consists of bone tissue, muscle tissue, nerve tissue, and blood tissue.

All living things contain protoplasm. It is the living substance of the cell, and contains the same elements found in foods. It differs from inorganic matter in the following ways:

1. Protoplasm is irritable; that is, it responds to the factors in the environment. For example, plants turn toward the light, while some living things are repelled by light. Both plants and animals are sensitive to touch, heat, light, and electricity.
2. It has the power to move and contract, just as, for example, your muscles contract to move parts of your body.
3. It takes in food materials and changes them into cell structures.
4. It selects the food it uses and absorbs it.
5. It gives off wastes that are harmful, such as carbon dioxide and nitrogenous wastes.
6. It takes in oxygen and oxidizes foods to get heat energy, and uses energy for motion.
7. It reproduces itself to form other living matter similar to itself.

Chemists have found that protoplasm may contain the same elements as nonliving matter contains. But it has other qualities which are not

apparent in any chemical analysis.

Although chemists know its chemical analysis, no chemist has as yet been able to combine these elements so as to make protoplasm. This is why living things are different from nonliving things.

REVIEW QUESTIONS

1. Why are plants our main source of food? **2.** Name three useful plants. **3.** Why is a green plant said to be a complete factory? **4.** What are the functions of each of the four main parts of a plant? **5.** What is a cell? What are its parts? **6.** What is protoplasm? How does it differ from inorganic matter? **7.** What materials used in your home come from cotton?

B How do green plants make food?

Green plants are the only living things that can make food. They supply not only their own food, but also the food for animals and for man himself. Without green plants, life on this earth could not exist.

A plant needs light to grow and make food. You no doubt have noticed that only certain plants grow well in the shade.

DEMONSTRATION

Put a green plant a few feet from the window in an otherwise darkened room. Keep it in this position for a day or two. Do the leaves seem to lean toward the

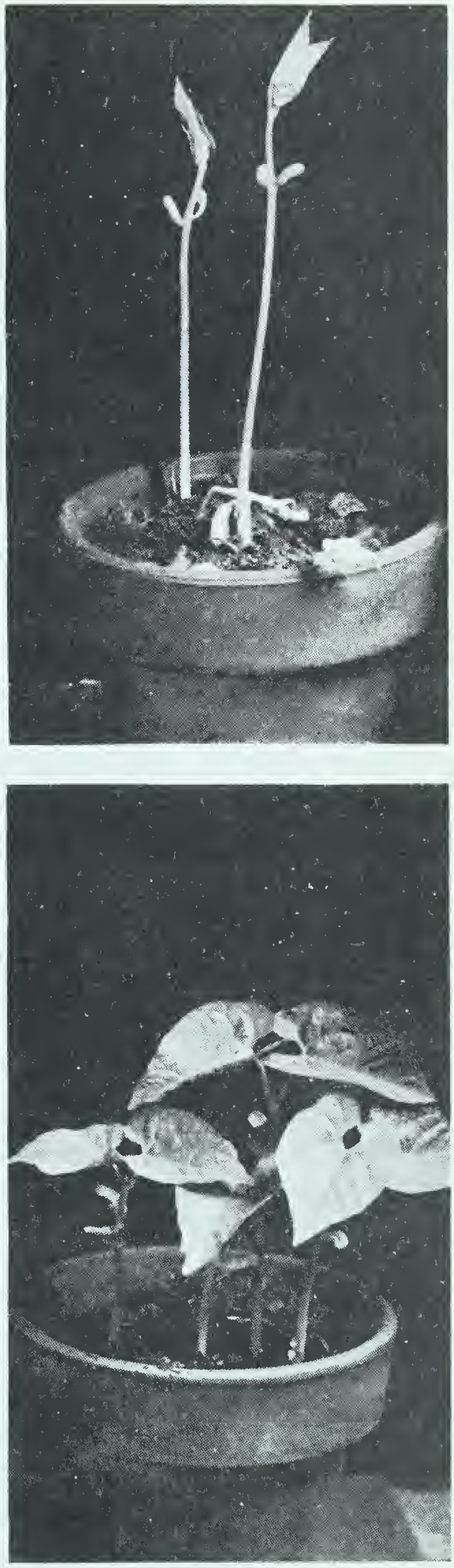


Fig. 17-4. The plant on the top was grown without light, while that on the bottom received ample light. How do you account for the long, thin stems of the plant on the top?

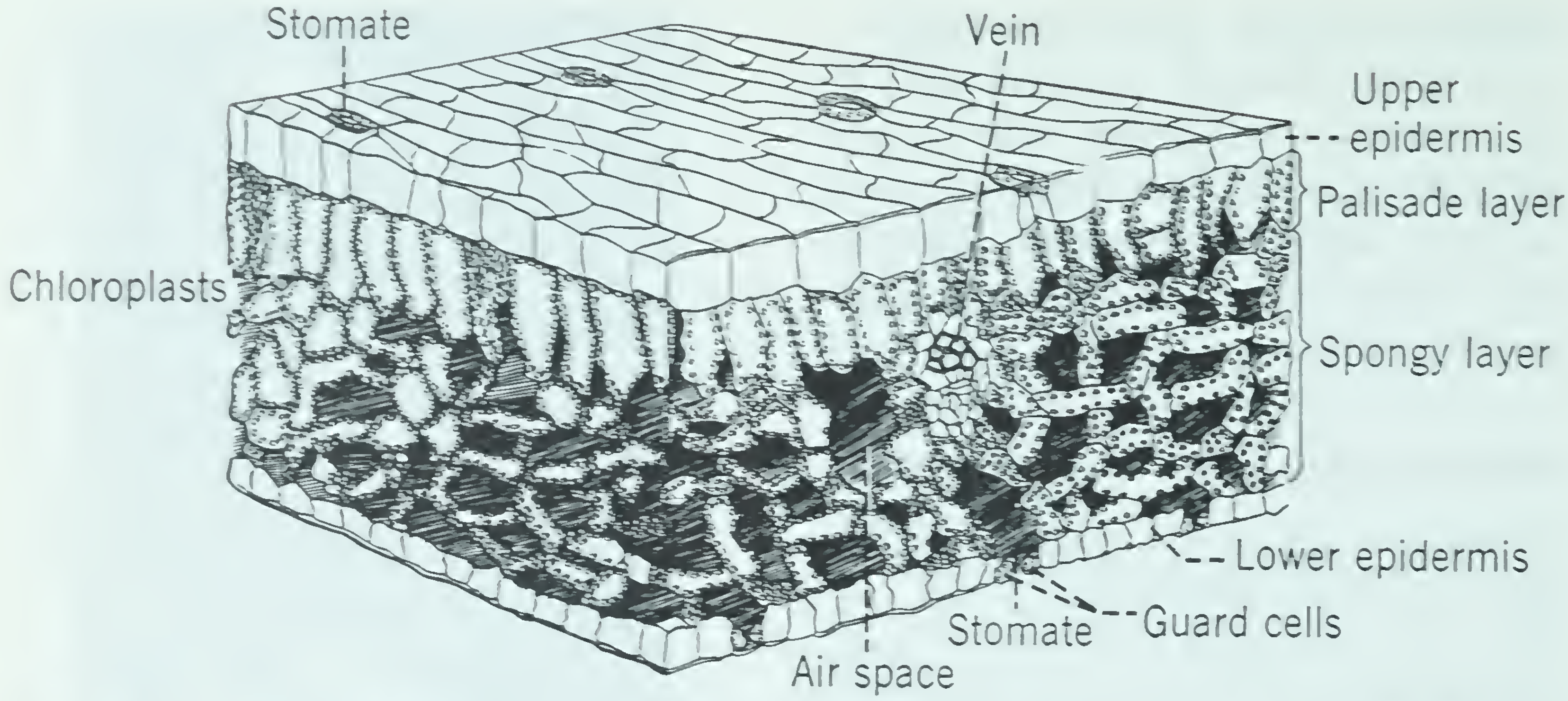


Fig. 17-5. When you look at a cross section of a leaf under a microscope, you realize how much like a well-planned factory it is. What is the function of each tissue?

source of light? Do you know of flowers that seem to "follow the sun"? Cover green grass with a small board for a few days. Result? How is celery bleached? Why are only the outside leaves of lettuce and cabbage green?

You have probably noticed many of these things without connecting them with the sun. Green plants lose their color if you keep them in darkness for any length of time. This green coloring in plants is called *chlorophyll* (*kloh*-roh-fill), and can only function in sunlight. Chlorophyll occurs in tiny granules in the cells of green plants.

Let us look at a green leaf.

DEMONSTRATION

Examine a prepared slide of a small cross section cut from a leaf. With the aid of Fig. 17-5, identify upper and lower epidermis, palisade layer, air spaces, spongy layer, stomates, and guard cells.

The upper and lower *epidermis* (ep-ih-*der*-miss) protect the inner tissues. The *stomates* (*stoh*-maytes) are small openings which let air enter the *air spaces*. Excess oxygen and water vapor are given off through the stomates. The *palisade* and *spongy cells* in a fresh leaf contain chlorophyll. These act, with the sun's energy, as the center of food manufacture. The spongy and palisade cells also digest food.

The *veins* carry digested food to other parts of the plant. They also bring supplies of water containing dissolved minerals from the soil. The *guard cells* around the stomates control the size of the openings. They close them in dry weather to keep in moisture.

The carbohydrate foods are starches and sugars. They are made in the green parts of plants and are called *carbohydrates* (kar-boh-*hy*-drates) because they contain carbon, oxygen, and hydrogen in varying amounts.

Scientists think that green plants make sugar first. Then, if the plant does not use the sugar at once, the extra sugar is transferred to the root or

stem. There it is changed to starch and stored for later use.

Now let us see if we can find any starch in green leaves. Sugar is certainly present, but it is not so easy to test for as starch is.

DEMONSTRATION

On a sunny afternoon pick a few leaves of any green plant. Geranium or nasturtium leaves are good. Drop them in boiling water for a few minutes to soften them, and then boil them in alcohol until the green color has been removed. (CAUTION: do not heat alcohol over an open flame.) Alcohol dissolves and removes the green color. Rinse the leaves in water, and test for starch by adding a few drops of iodine. Rinse in water. Color? Conclusion? (NOTE: If the color is black or brownish-purple, starch is present. Scientists have found that when iodine is added to a substance and a blue, black, or purplish color appears, it indicates the presence of starch. Hence this is known as the starch test.) Why is the green coloring matter removed before the iodine is added? If in doubt, add iodine to a green leaf.

Put a few drops of iodine on a piece of bread; on the cut surface of a potato; and on some flour. Results? Do green leaves contain the same substance as the foods tested? Where was the starch evidently manufactured?

Now that we know that starch is present in green leaves, let us find out what compounds are used to make it.

DEMONSTRATION

Gently heat some starch in a test tube. Result? What collects on the inside of the tube? Lower a stirring rod with a drop of limewater on the end of it into the test tube. Result? Is carbon dioxide found in starch? Where did the water and carbon dioxide come from? (NOTE: heat the starch very slowly.)

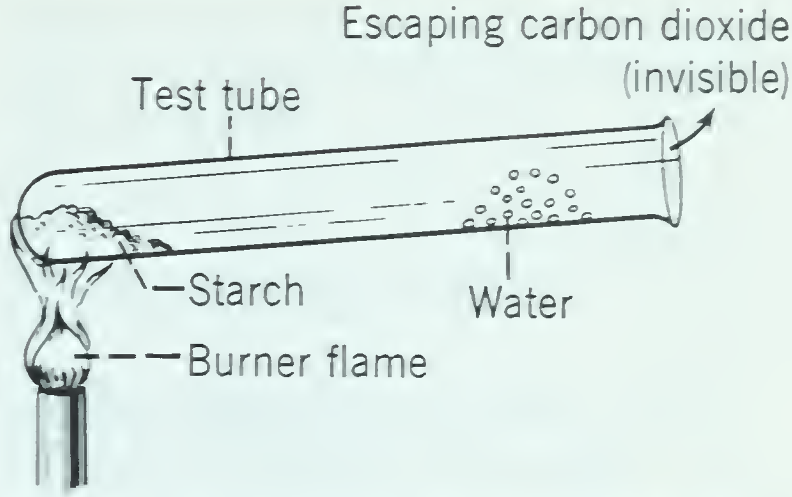


Fig. 17-6. Heat breaks up starch into its compounds, water and carbon dioxide.

Heat a small quantity of starch in a test tube until it is charred. What is the black substance? Was more heat needed this time?

The compounds *carbon dioxide* and *water* are used in forming starch. The starch was first heated gently so free carbon would not be formed. Gentle heat is enough to break starch into its compounds, but not enough to produce carbon dioxide by oxidation if free carbon is present. The carbon dioxide that was used to make the starch came from the air through the stomates. The water came from the soil.

We know that the compounds carbon dioxide and water are used in making starch. But what we do not know is how they are bound together when starch is made. Energy and some way to use this energy is needed.

DEMONSTRATION

Cover part of both sides of a leaf of a potted plant with black paper or cork, so

as to keep out the sunshine from the covered parts. Let the plant stand in sunshine for several hours. Remove the leaf, and boil it in alcohol to remove the chlorophyll. Test for starch. In what parts of the leaf is starch found? Not found?

Sugar and starch are made in green leaves only in the sunlight. The world's supply of food is made during the long spring and summer days when there is plenty of sunlight.

Here is another demonstration to show us that green leaves are necessary to make food.

DEMONSTRATION

Get a plant whose leaves have both green and partly colorless spots or white stripes. Put the plant in sunshine for a few hours. Remove the chlorophyll as before, and test for starch.

The interesting thing is that starch is present where there is chlorophyll. Where there is no chlorophyll, there is no starch. It is just as important for chlorophyll to be present as sunshine. The sun supplies the energy to run the machinery in the leaf where carbohydrates are made. We can think of the chlorophyll as the machinery used in the food-making process.

The process of making food in green plants is called photosynthesis. This word *photosynthesis* (foh-toh-*sin*-thih-sis) really means: "putting together in the presence of sunlight." What is put together in the green plant to form carbohydrates?

Two *raw materials* are needed to supply the carbon, hydrogen, and oxygen which all carbohydrates contain. These are: (1) *carbon dioxide;* and (2) *water.*

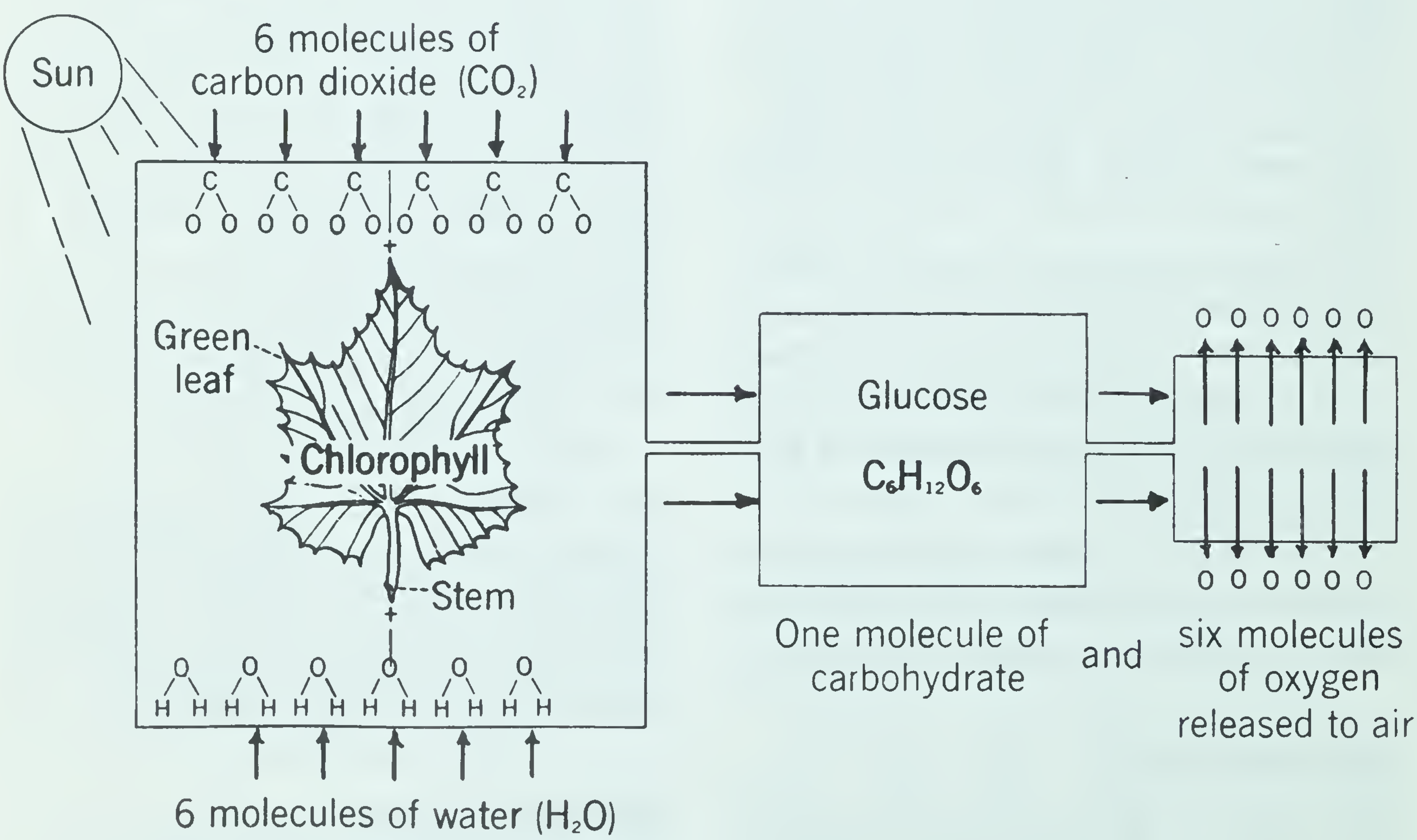


Fig. 17-7. Photosynthesis is the process by which green cells of plants use light in combining carbon dioxide and water to form sugar. Oxygen is released as a waste product.

Recent research shows that the green plant has the ability to take hydrogen from water and combine it with carbon dioxide. Thus it forms simple sugars which then may be converted into starch. The plants get water from the soil through their roots. Carbon dioxide enters through the stomates of the leaves.

The water and carbon dioxide are changed by the chlorophyll into sugar. This process only goes on when light is present. Remember that photosynthesis will only occur when these four factors are present: (1) water; (2) carbon dioxide; (3) light; and (4) chlorophyll.

Plants make food by the process of photosynthesis. Recently, for the first time chemists have learned more about the chemistry of this wonderful process. They have written a simplified equation to show the materials and how they react.

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

This means that six molecules of carbon dioxide unite with six molecules of water to produce one molecule of sugar and six molecules of oxygen. Note that the oxygen is given off as a waste product of photosynthesis. Fig. 17-7 shows this equation even better.

DEMONSTRATION

Into each of two glass jars put some fresh water. Put in each jar some water plants. Cover each plant with an inverted funnel as shown in the diagram in Fig. 17-8. Invert a test tube full of water over the tips of the funnels. Put one in a dark closet for a few hours, and the other one in direct sunlight. Carefully remove the test tubes containing the escaping gas from the green plants. Invert them and test for oxygen with a glowing splint. Which tube contains oxygen?

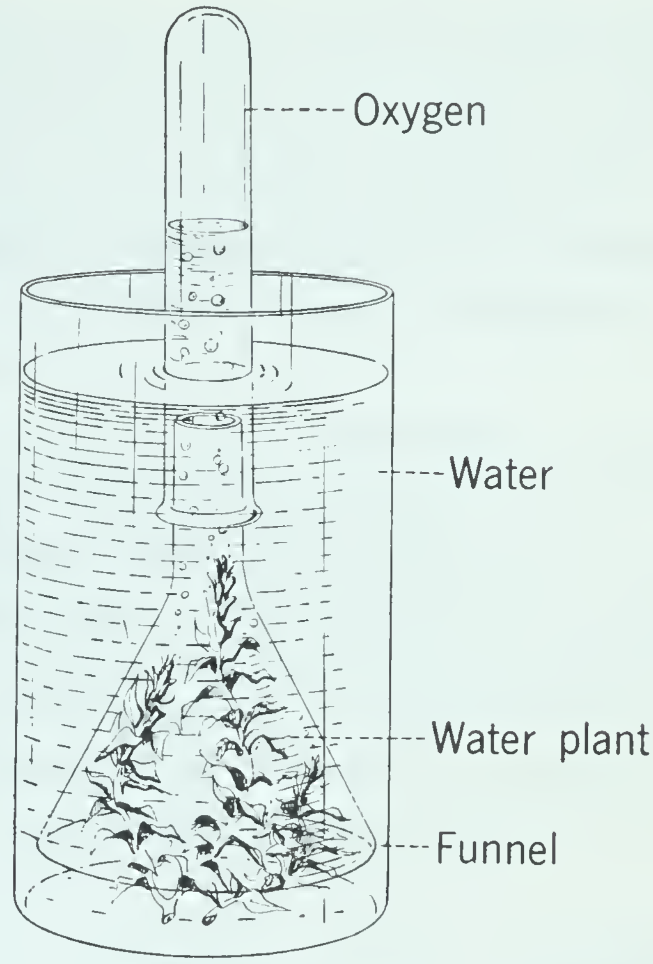


Fig. 17-8. In this experiment, you can see the oxygen bubbles rising in the tube from the green plants at the bottom of the funnel. How can you prove this is oxygen?

Chemists have found that the oxygen given off in photosynthesis has the same volume as the carbon dioxide used. This free oxygen is given off into the air through the stomates. It is used by all living things in breathing.

Plants also make proteins and fats. After sugar and starch are made, the plant uses them as the basis for making proteins, fats, oils, or waxes. Sunlight and chlorophyll are not necessary for these processes.

Remember that carbohydrates are the basis for the making of all other food substances, except minerals.

The process of photosynthesis is as follows: the sun's energy assisted by

chlorophyll, builds sugar, and finally starch, out of carbon dioxide and water. The energy of the sun is stored in the carbohydrates made. The oxygen is released as a waste product through the stomates.

REVIEW QUESTIONS

1. What raw materials are used in making carbohydrates? **2.** What are the principal parts of a leaf? **3.** What is the by-product produced in the manufacture of carbohydrates? **4.** What is the test for starch? **5.** What is photosynthesis? Why is it such an important process?

C How do plants get water and dissolved minerals from the soil?

Plants absorb liquids by the process of osmosis. Remember, no solid material can pass through a cell wall. Everything which enters or leaves a cell must be dissolved in water. How, then, does a plant get materials from the soil?

Root hairs are projections of tiny cells on the surface of small roots. There are hundreds of root hairs on an average root and they look like a mass of cobwebs (see Fig. 17-10 on page 497.)

These root hairs absorb water and anything dissolved in water through their thin walls. This process of water absorption by any cell is called *osmosis* (os-*moh*-sis). Let us see how it works.

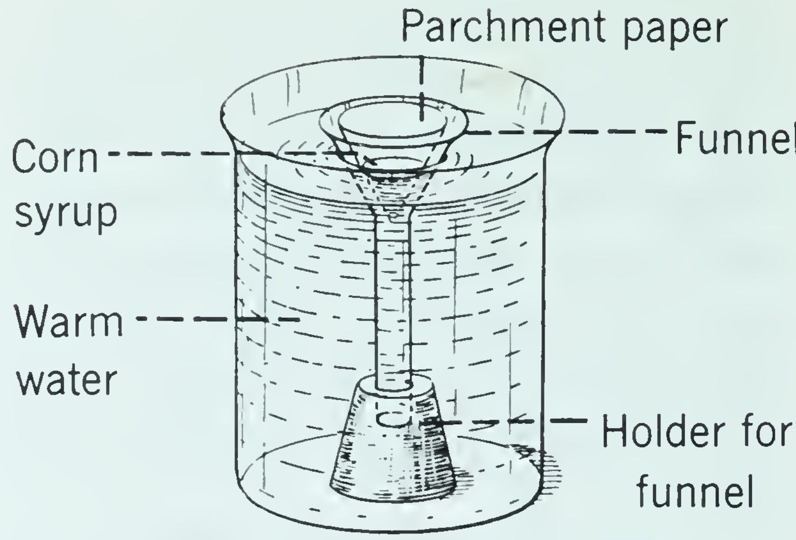


Fig. 17-9. The less concentrated solution (water) passes through the parchment paper more rapidly than the more concentrated solution (syrup).

DEMONSTRATION

Fit a piece of parchment paper tightly in a funnel in the same manner as a filter paper is fitted. Fit the lower end of the funnel with a one-hole rubber stopper to hold it upright. Put the funnel in a 1000 cc. flask or a small battery jar as shown in the diagram in Fig. 17-9. Fill the jar with warm water to the top of the funnel. Put about three teaspoonfuls of warm corn syrup that has been colored with red or black ink in the parchment cone that rests in the funnel. Let stand ten or fifteen minutes. Result? What must have happened? How does soil water get into a root hair? The syrup represents the sap in the plant. The water in the jar represents the soil water. Is the direction of flow greater from the water to the syrup or from the syrup to the water? How can you tell?

Reverse the process. Put the syrup in the jar and the water in the parchment paper. In which direction is the rate of flow the greater?

Soak a dry prune overnight in water. Result? How do you account for this result? In which direction is the flow the greater?

Repeat the experiment by putting wa-

ter and starch in the parchment paper and water in the jar. Result?

Only soluble materials will pass through the parchment paper you use in this experiment. The parchment paper represents the cell wall. The direction of flow in osmosis is from *areas of greater concentration* to *areas of lesser concentration* of the same material. The syrup flowed from the funnel (area of greater concentration of syrup) to the water (area of lesser concentration of syrup). The water flowed from the water area (greater concentration of water) through the paper to the syrup (lesser concentration of water). The water flowed up into the syrup more rapidly than the syrup passed down into the water.

Nothing can enter the cell wall unless it is *soluble*. *Soluble* means that the material or substance will completely dissolve in water. *Insoluble* means that a substance will not dissolve in water.

Soil water contains dissolved minerals. As surface water sinks into the ground, it slowly dissolves the minerals that are present in the soil. Because of this, the soil water contains varying amounts of soluble nitrates, sulfates, carbonates, and phosphates. Green plants can then absorb these minerals and use them to build their body tissues.

DEMONSTRATION

Put some fertile soil in a funnel fitted with filter paper. Pour distilled water or rainwater on the soil and catch the filtered liquid. Evaporate the filtered liquid. Result? Explain. Why do we use distilled water or rainwater?

What is the nature of soil water and how is it formed? Where does the plant get its minerals?

Plants absorb water through the root hairs. An experiment will prove the presence of these hairs.

DEMONSTRATION

Put a piece of wet blotting paper between two pieces of glass about 4 inches square (see Fig. 17-10). Scatter radish seeds on the blotting paper and fasten all together with a rubber band. Test tubes, or tum-

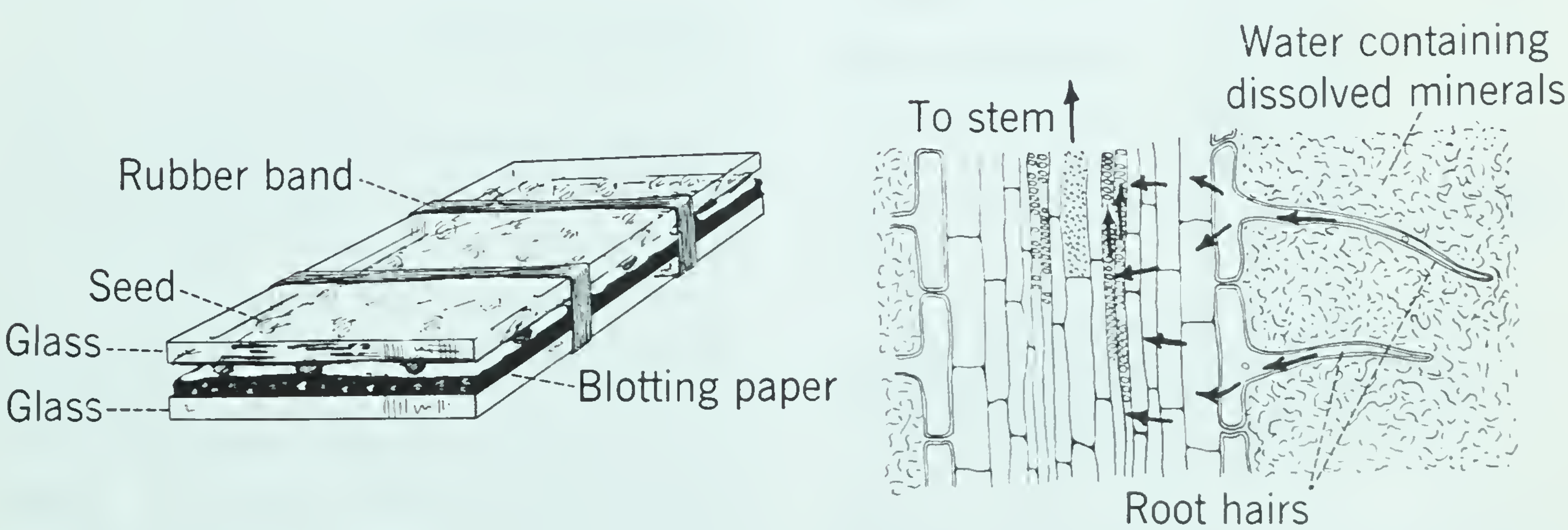


Fig. 17-10. The left drawing shows growing root hairs. On the right, you can see that water and dissolved minerals enter the plant through the root hairs.

blers, lined with blotting paper, will also serve. Moisten the blotting paper daily. Do fuzzy, hairlike structures appear on the rootlets in a few days?

Examine some of the hairlike growths with a lens or a microscope, if possible.

Soil water passes into the root hair, then into neighboring cells of the root and into tubes in the stem by osmosis. These tubes extend up through the stem into the leaf to form a portion of the veins.

DEMONSTRATION

Cut off a portion of two or three celery stalks near the base. Put the cut ends of the stalks in some red-colored water. See Fig. 17-11. Let stand for a few hours. Results? Does the water go up into the stem? Into the leaves? Where do the veins of leaves evidently begin? Cut cross sections of one of the stalks in several places. What is the use of the stringy threads in the stem? Are they really water pipes? What might the red coloring matter left in the leaves represent?

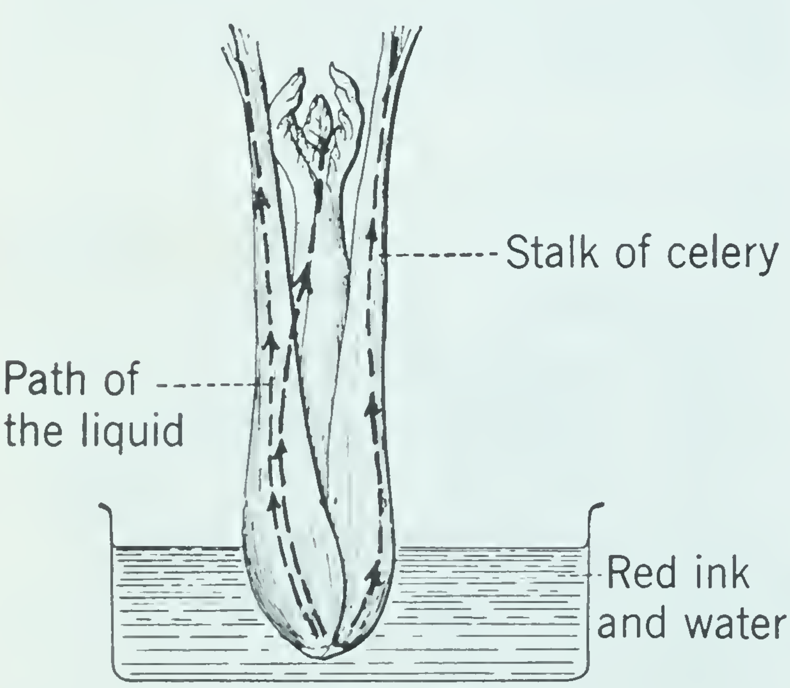


Fig. 17-11. The stem and leaves carry water and dissolved minerals from the roots to other cells in the plant.

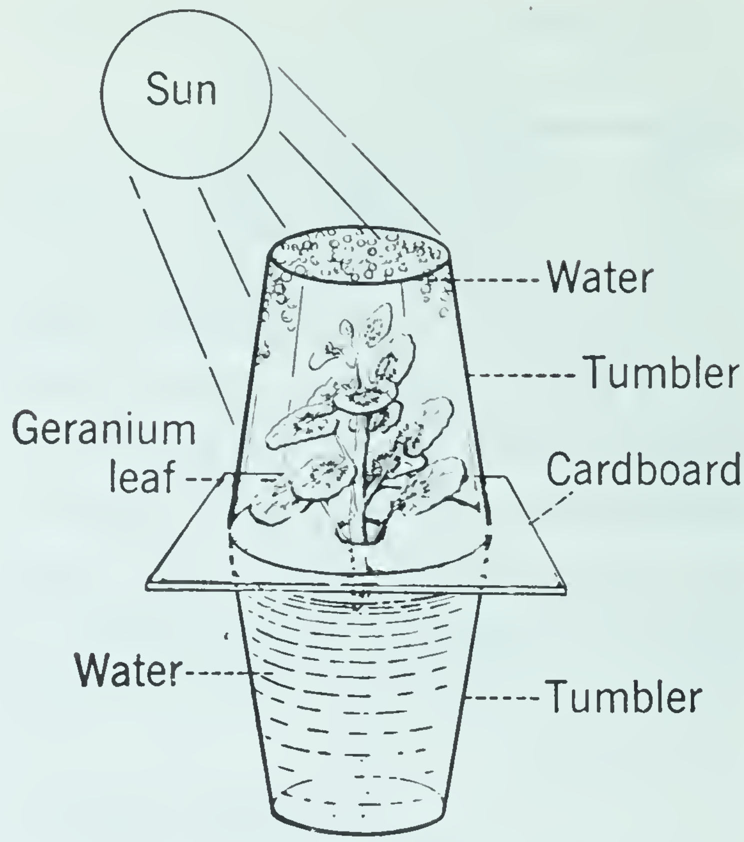


Fig. 17-12. Transpiration occurs in leaves of plants during the daylight hours.

The water and dissolved materials passing through the root hairs are carried up through the stem to the leaves. They are used in food manufacture.

Leaves give off excess water through their stomates.

Transpiration is the evaporation of excess water from the leaves. Large amounts of water are needed to furnish a small amount of mineral matter. Then what becomes of the excess water? Here is the answer.

DEMONSTRATION

Put the stem of a large shoot such as a geranium shoot through a hole in a piece of cardboard large enough to cover a tumbler. Fill the tumbler nearly full of tap or well water (see Fig. 17-12). Invert another tumbler over the leaf. Does moisture collect on the inside of the upper tumbler after a few hours? What did this water bring with it into the plant? Why do plants absorb so much soil water?

Fig. 17-13. Why does cultivation of the soil help the roots of plants to get water more easily?

An average tree will give off about 900 pounds of water on a dry, sunny day. A large sunflower plant may give off as much as a quart of water in one day, and the grass on a vacant city lot may lose a ton a day. We are not conscious of this activity because water vapor is invisible.

Plants use dissolved minerals in the soil water to make proteins. *Proteins* (*pro*-tee-ins) are complex food substances. They are necessary in building and repairing the body cells and in making protoplasm.

Plants make proteins from sugar and starch by combining them with soluble salts of nitrogen and sulfur and sometimes phosphorus. Protein formation can occur in any cell of the plant. It can take place at all times, and does not need sunlight.

REVIEW QUESTIONS

1. Where does a plant get the minerals it uses? **2.** What is osmosis? Under what conditions does it occur? **3.** If a strong solution of salt water is put around the roots of a plant, why does it wither and die? **4.** What are root hairs? **5.** How can we show the presence of dissolved minerals in water? **6.** What elements are used in making protein? **7.** What is transpiration in a plant? **8.** How do minerals in soil water reach the plant leaves?

D How do flowers produce seeds?

The flower forms seeds which reproduce the plant. We all admire flowers, but how many of us know their importance to the plant? Without them there would be no fruits or seeds. The drawing in Fig. 17-14 will help you to identify the parts of a flower.

The outer parts of a flower are usually green and are the *sepals* (*see*-pals). The colored parts just inside are the *petals*. Next, we find the *stamens* (*stay*-mens) which have an *anther* on top of each. The anthers contain a pow-

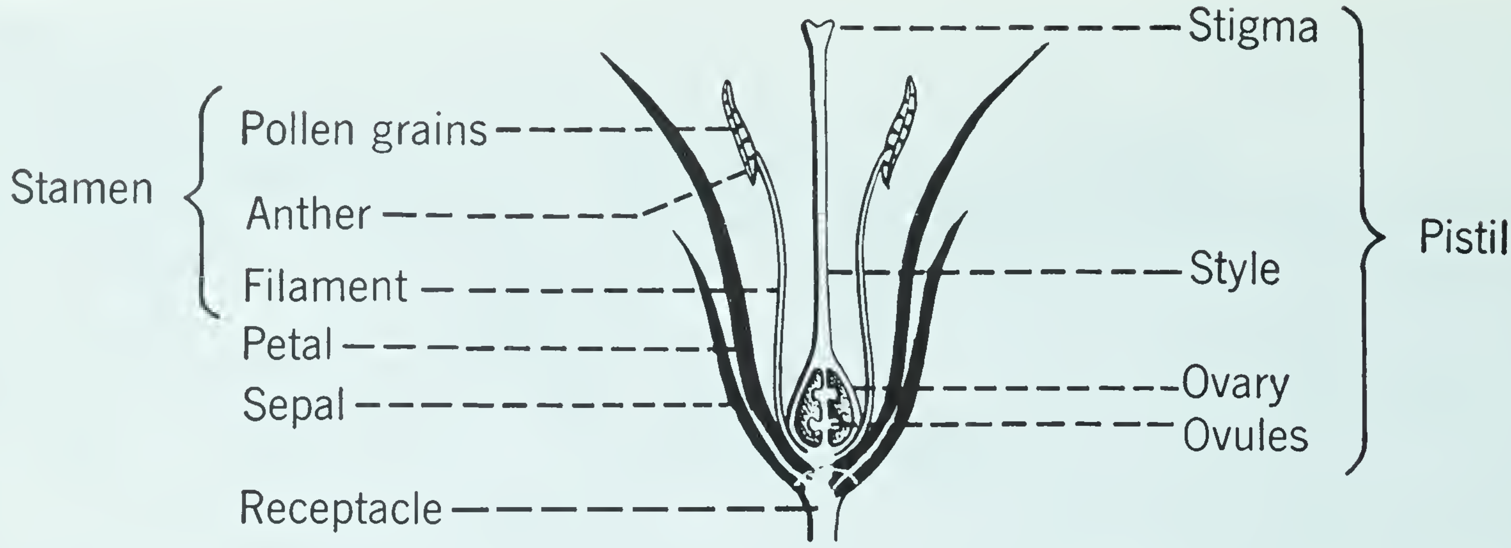


Fig. 17-14. Explain the function of each of the parts of the flower in this drawing.

dery substance called ***pollen*** (*pah*-len) which is necessary in reproduction.

The ***pistil*** is the innermost part of the flower. It consists of three parts: (1) the *stigma* at the top; (2) the *style*, or long tube; and (3) the *ovary*, or swollen part at the bottom. The ovary becomes the fruit.

If we cut across the ovary, we find small *ovules* inside. These become the seeds as the fruit ripens.

The transfer of pollen from the anthers to the stigmas of flowers is pollination. Pollen may be transferred by wind, water, gravity, and insects. If the pollen from an anther falls on the stigma of the same flower, we say these stigmas are ***self-pollinated.*** If the pollen is transferred from the anthers of one flower to the stigmas of another, then these stigmas are ***cross-pollinated.*** Cross-pollination usually results in the production of the best or most abundant seed.

Plant breeders remove the anthers at the time the flower opens. They tie a paper bag around the rest of the flower to prevent accidental cross-pol-

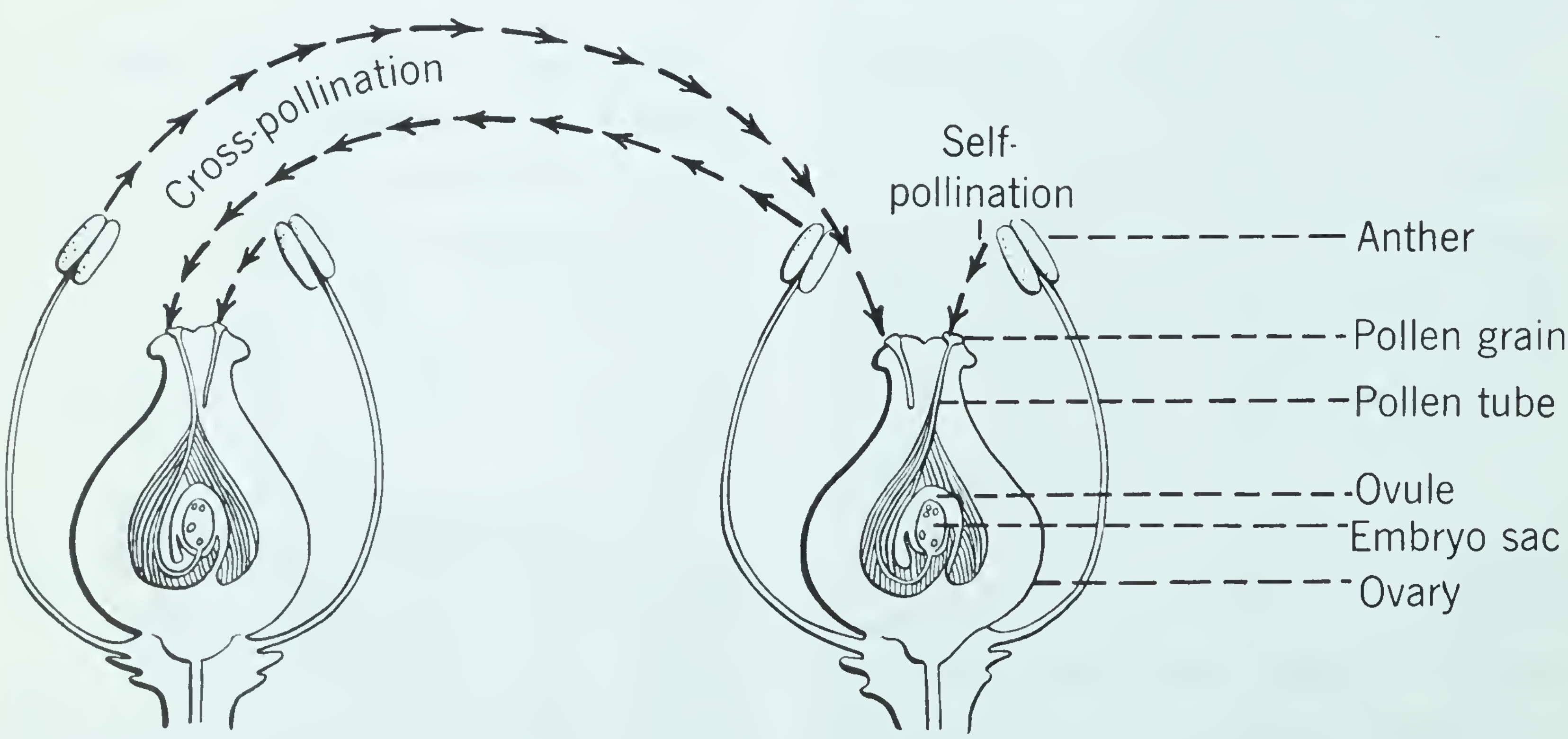


Fig. 17-15. Pollination occurs in a flower either by cross-pollination or self-pollination.

Fig. 17-16. Pollen may be transferred by many kinds of insects, especially bees.

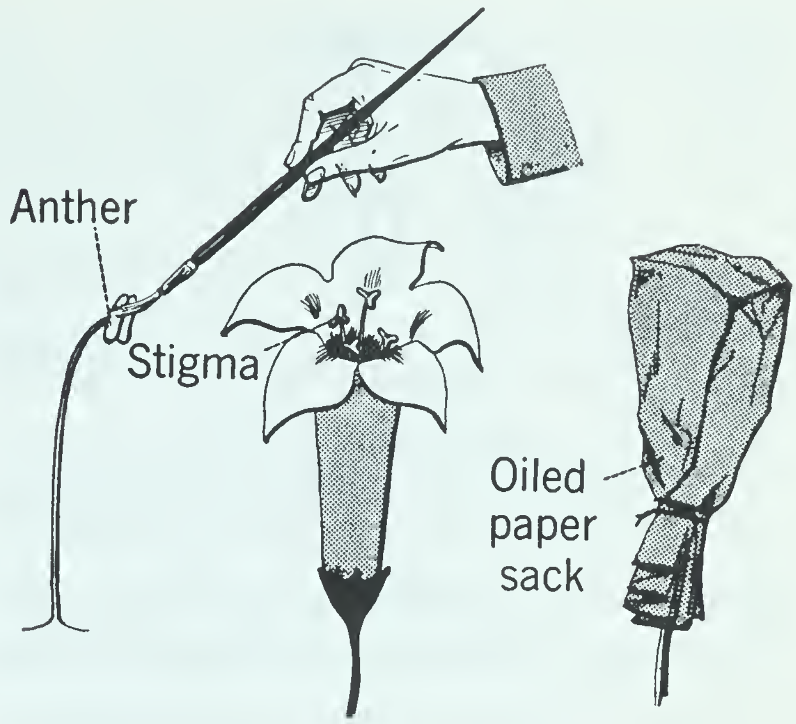


Fig. 17-17. In artificial pollination, pollen from the anther of one plant is transferred to the stigma of another plant by mechanical means.

lination. Then, when the pistil is ripe, they transfer some pollen with a fine brush from the anthers of a closely related flower. They label the flower and put the paper bag back on again. Thus they get a new type of plant which is different from both plants. This is called ***artificial pollination.***

A plant begins to form seeds after pollination. If you put some pollen in a weak solution of grape sugar or molasses, it will sprout and produce tiny tubes.

Pollen sprouts in the same way on the sweet, sticky stigmas. It pushes its tube down through the style until the tip reaches the ovary. Then it pierces the wall and enters an ovule.

Each ovule contains an *egg cell.* Each pollen tube contains a ***male sex cell,*** called a *sperm.* When a *sperm* unites with an *egg,* we call the process ***fertilization.*** The fertilized egg then grows into a young embryo

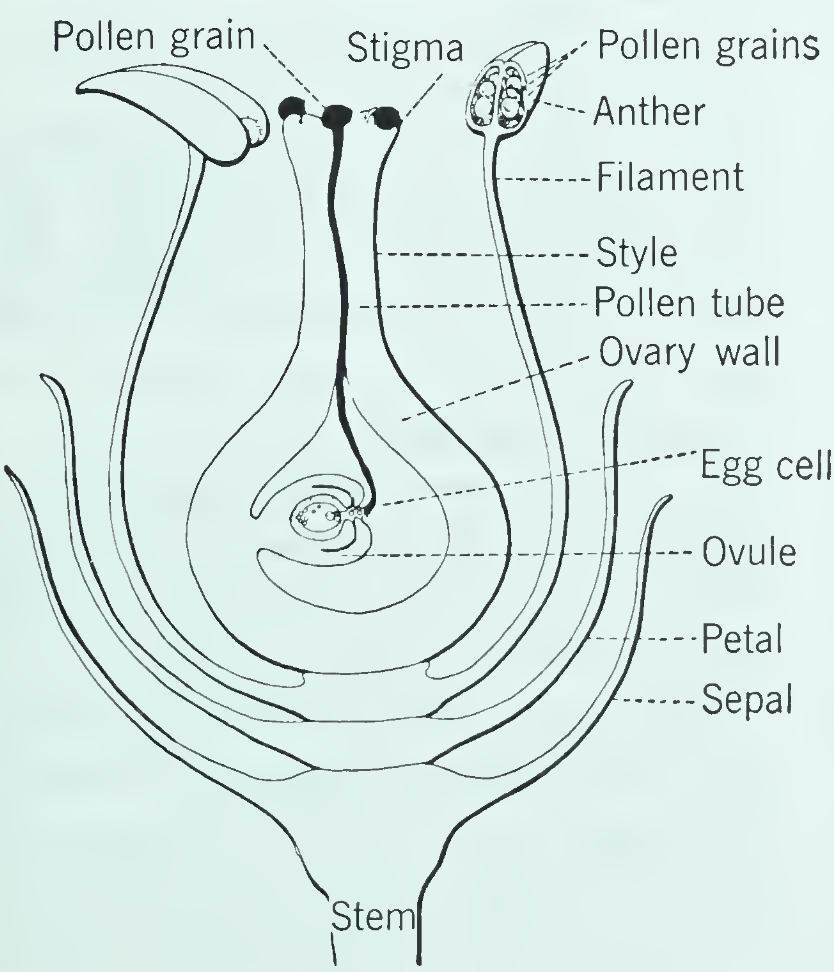


Fig. 17-18. Fertilization occurs when an egg cell unites with a sperm. Here you see a cross-section of a flower which shows you the parts more clearly.

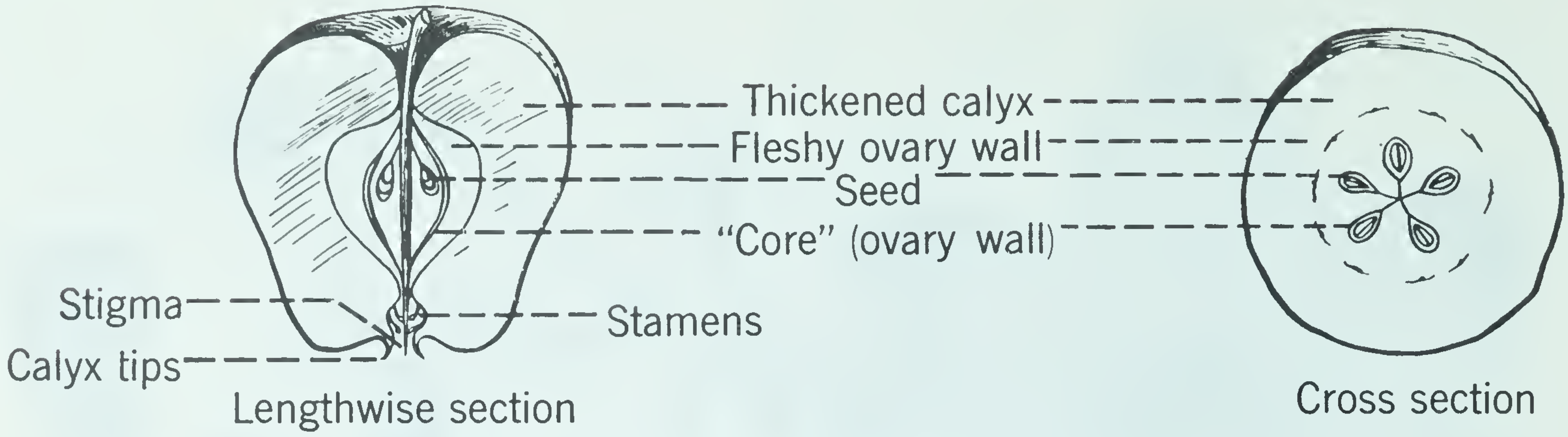


Fig. 17-19. How does the apple fit the definition of a fruit in the text below?

plant. The difference between an ovule and a seed and an ovary and a fruit is merely one of fertilization. Before fertilization each is called an *ovule* and an *ovary*. After fertilization the ripened ovary becomes the fruit and the ovules become the seeds.

Nearly all living things, except the lowest forms of plants and animals, have eggs and sperms and form embryo plants and animals as a result of fertilization.

A fruit is the ripened ovary, including the other parts attached to it. Many parts of plants which we call vegetables are really fruits. Tomatoes, eggplants, and squash are fruits. So are the seed pods of beans, peas, and peanuts.

PUPIL ACTIVITY

Look at a bean or pea pod. Find the ovary, style, and stigma. What is the difference between them? Open the pods and find the seeds. Where are they fastened? Note that each is fastened by a small stalk to the ovary wall. Of what value is this stalk to the embryo? Are all the ovules developed into seeds? If not, explain.

A bean or pea pod is the ripened pistil. Some of the ovules did not develop into seeds because they were not fertilized. A ***fruit*** is the ripened ovary with all the parts attached to it. (See Fig. 17-19.)

PUPIL ACTIVITY

Remove the outer coat of a bean or pea seed which has been soaked overnight. Into how many parts (cotyledons) does the rest of the seed naturally separate? Remove one cotyledon carefully, and find two minute leaves (plumule). Find a rodlike part (hypocotyl).

The ***plumule*** (*plew*-mule) consists of young leaves. The ***hypocotyl*** (*hy*-poh-kot-ill) is the beginning of the stem and also the root. The ***cotyledons*** (kot-ih-*lee*-dons) are storehouses of food which has been stored by the parent plant. These parts make up the tiny ***embryo plant.***

A seed is a young embryo plant surrounded by one or more protective coats. It contains stored food for the young embryo to use in growth.

When you plant the seed, its coat swells as it absorbs water from the soil. The hypocotyl pushes out of the seed coat, using the stored food in the cotyledons. When the first real leaves

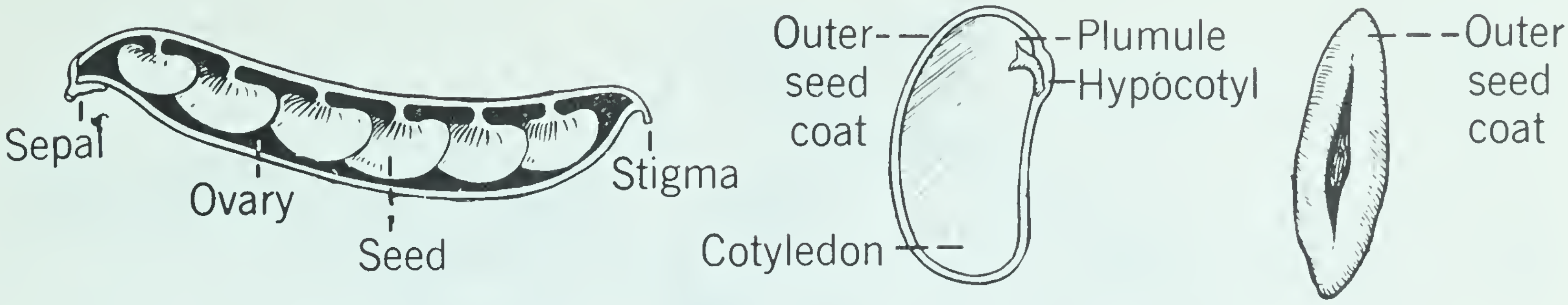


Fig. 17-20. These drawings show the different parts of the bean seed.

develop from the plumule, the young plant is on its own. Then it grows and is ready to produce flowers and start the process of reproduction over again.

REVIEW QUESTIONS

1. What is the function of each part of a flower? **2.** What is the meaning of pollination? **3.** Distinguish between self-pollination, cross-pollination, and artificial pollination. **4.** How is the egg cell of a flower fertilized? **5.** How is a seed developed? **6.** What is the difference between a fruit and a seed? **7.** What are the parts of a fruit? Of a seed?

E How does a seed use its stored food in germination?

A seed will not germinate unless air, water, and some heat are present. Dry seeds can be kept for a long time without sprouting. Some seeds lie quiet for years and yet grow when the right conditions occur. When the embryo of a seed begins growth and pushes out through the seed coat, it sprouts, or germinates. *Germination* (jer-min-*ay*-shun) is the growth of the young embryo after a period of inactivity in the seed. By doing the following activity, you will see what conditions are necessary for seeds to germinate.

PUPIL ACTIVITY

This exercise on the germination of seeds is in the form of a controlled experiment. It should be planned in such a way that only one factor is allowed to vary in each part. You should use the same kind of seeds throughout.

(A) Plant seeds of beans or peas in soil in a box one inch deep and a distance apart of one inch. Count the number of seeds planted. Now plant two more boxes with seeds under the same conditions as the first box. Add the same amount of water to all of the boxes. Put one box in the classroom, another box in a cold place, and the last box in a very warm place. The light should be the same. What are the controls in the experiment?

(B) Repeat part (A) with three boxes planted under the same conditions. Put one box in direct sunlight, one in a dark room, and the other in a room on the north side of the building. These rooms should all be at about the same temperature. Result?

(C) Plant seeds in two bottles with the same soil, and at the same depth as in parts (A) and (B). Keep the bottles near each other in the same room. Remove air from one bottle and seal it. Leave the other bottle open to the air.

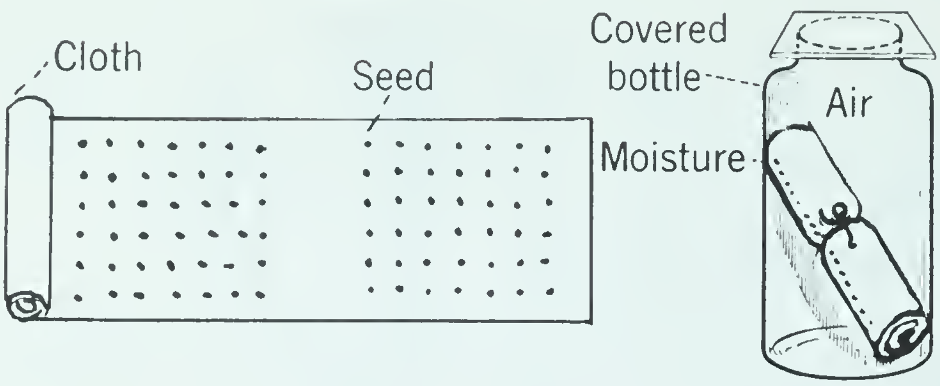


Fig. 17-21. To germinate seeds, water, air, and the right temperature are necessary.

(D) Plant seeds in sand, loam, and sawdust. Also plant some seeds between two blotters which are kept damp. The variable here is soil. Is soil needed for germination?

(E) Devise steps for planning an experiment to determine the effect of planting seeds in a soil which is thoroughly dry, the same soil medium wet, and the same soil thoroughly wet. Result?

(F) Devise a plan for measuring the effect of the depth at which seeds are planted on germination.

You should keep the seeds you have planted under the same conditions as when you began the experiment. And do not confuse germination with growth. When the seed sprouts, it has *germinated*. But when it forms its own roots and leaves it has started to *grow*.

You can germinate seeds without soil or light. All they need is water, air, and satisfactory temperature.

Seeds tested before planting time will save many crop failures. Early mistakes in planning the garden are hard to correct later. The most common mistakes are failure to prepare the soil properly, the use of poor seed and seedlings, improper methods of planting, and poor soil. Packaged seeds are usually tested by the company that sells them. Here is how they do it.

DEMONSTRATION

Count out 50 seeds each of peas, corn, and beans. Spread one lot on the end of a flannel cloth that has been dampened with water but not saturated. Double the cloth over to cover the seeds. Put another lot on this flap and re-cover each time until all lots are wrapped in the damp cloth. Put the folded cloth in a plate and cover it with another plate to prevent too rapid loss of water. Set in a warm place and examine daily to see if all the seeds are sprouting. If 45 out of 50 sprout, the seeds are fairly good. Test radish seeds by putting them between two damp blotters, or put the lots so wrapped in covered bottles instead of covered plates.

The expected percentage of germination is commonly printed on the seed package, along with the year in which they are expected to be planted for best results.

Digestion is the changing of insoluble foods into soluble substances. The food supply in seeds is stored there by the parent plant for the use of the young embryo plant until it can make its own food. The foods are stored in the seeds in an insoluble form so that they will not be dissolved by water and consequently lost. How, then, can insoluble substances be changed into soluble substances? The answer is by digestion.

Digestion occurs in germinating

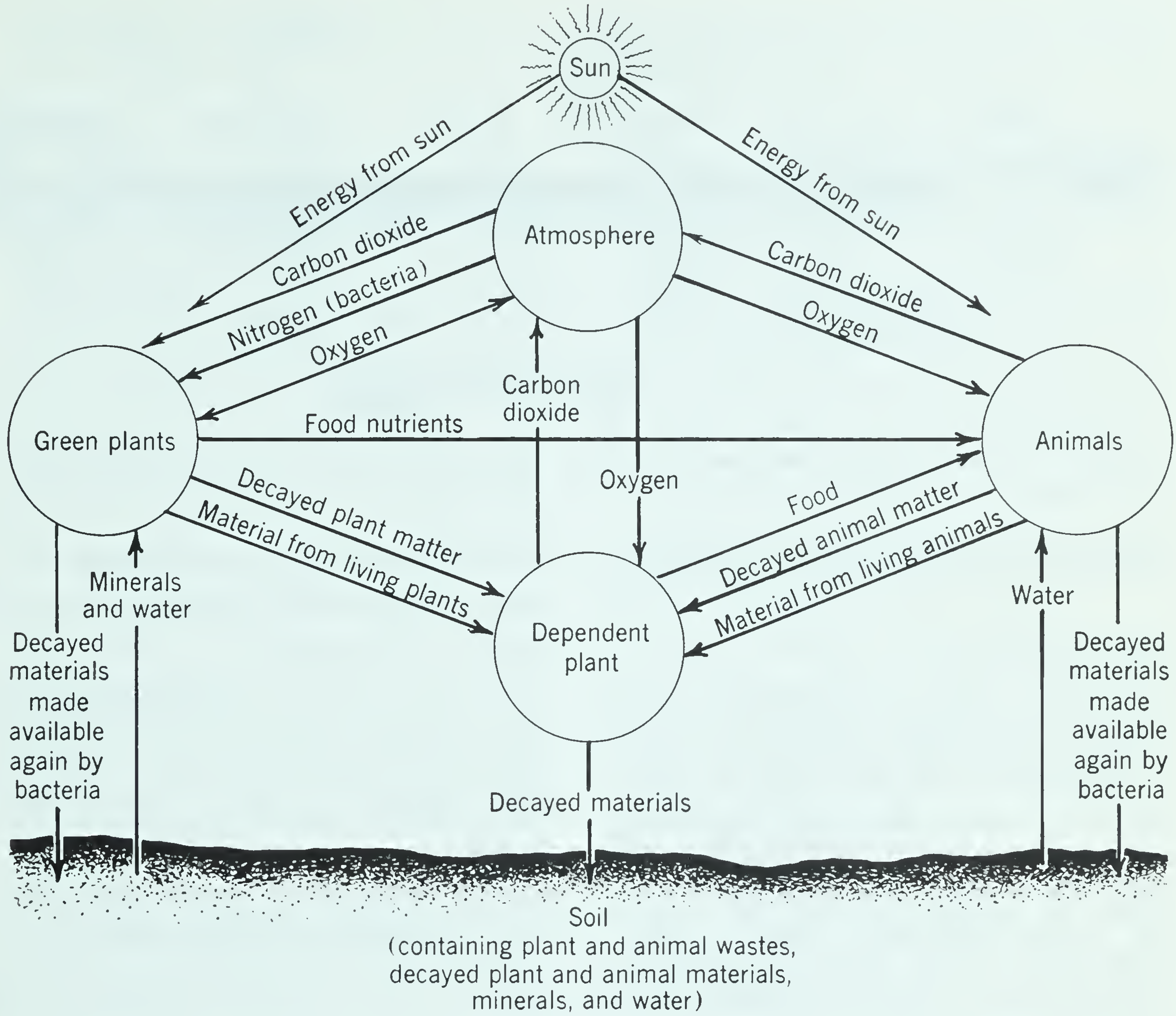


Fig. 17-22. The continued production of food depends on the sun's energy and the growth and decay of plant and animal life.

seeds. Insoluble foods will not pass through cell walls. How, then, does the young embryo plant use its stored food? The following demonstration will help you to answer this question.

DEMONSTRATION

Crush some sprouting bean or pea seeds or some corn grains. Put the crushed seeds in a test tube and cover them with water. Let stand for a short time. Test for sugar by heating gently with Fehling's solution. Result? Conclusion? Test unsprouted seeds in the same way. Result? Conclusion?

It is clear that the young embryo plant digests its stored food. When the proper conditions for germination are present, digestion begins, but not before.

Then the digested food passes by osmosis from the cells in which it was stored into the young growing cells.

Assimilation is the process of changing digested food into protoplasm. *Assimilation* (as-sim-il-*ay*-shun) is a constructive process. When the digested food reaches new cells, the protoplasm changes the food into more protoplasm. Thus cells are con-

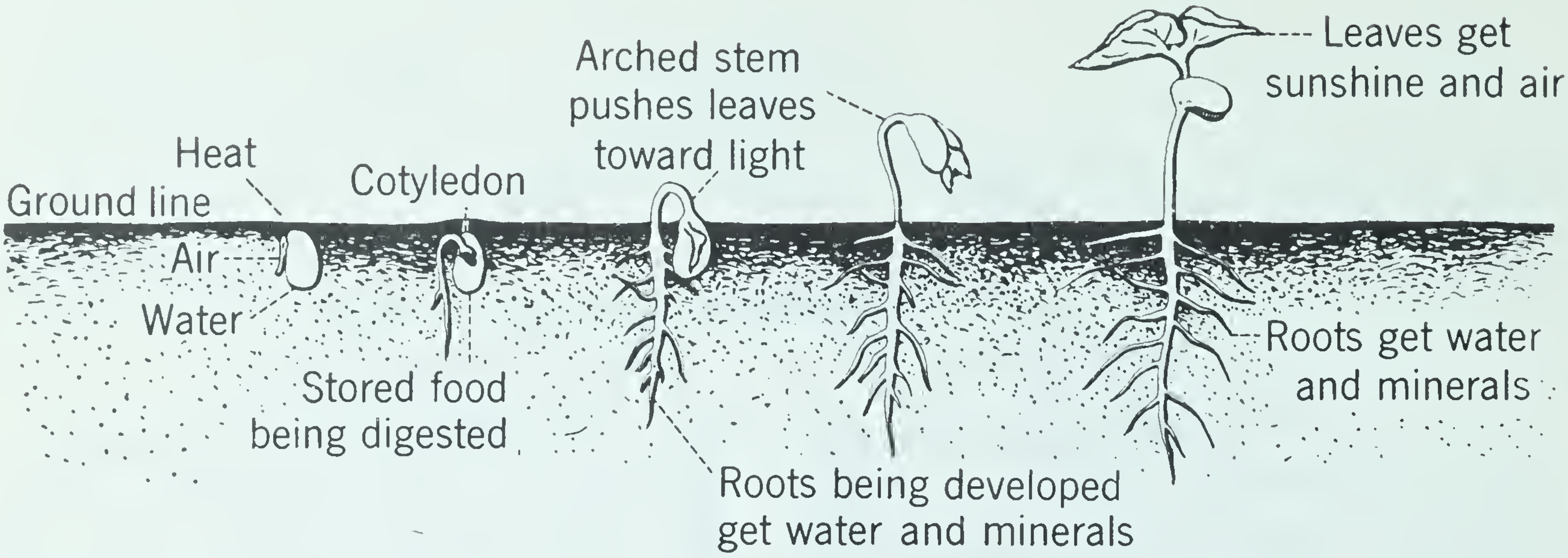


Fig. 17-23. From these drawings, you can see the various stages in the germination of the bean.

stantly fed and new cells are produced.

PUPIL ACTIVITY

Plant some soaked bean seeds in pots or shallow trays, with holes in the bottom for drainage. Plant the seeds in moist sand or sawdust. Use a box with glass sides for studying the developing roots. Keep the temperature at about 72° F. and water occasionally. Remove specimens from day to day, until you get a complete series up to the time green leaves first appear.

Make sketches of these changes every other day for about two weeks. This series of sketches should show just what has become of each part of the embryo. What does the change in the size of the embryo indicate? What becomes of the plumule? of the hypocotyl? Of the cotyledons?

The plumule of the bean or pea develops into the first true leaves of the plant. The hypocotyl develops into the stem in one direction, and the root in the other direction. In the case of the bean seed, the two cotyledons are pulled out of the soil by the arched hypocotyl. They serve not only as storehouses of food, but also as *seed leaves* until the food is exhausted, then they fall off. They become green because of the presence of chlorophyll. The cotyledons of many other kinds of seeds remain underground. Try growing some other seed plants. Examine each one of the various stages as they develop.

The young plant produced from a seed is called a ***seedling.*** After using up the supply of food stored by the parent plant, it must depend on its own roots and leaves to supply the materials necessary for its growth.

REVIEW QUESTIONS

1. What must be present before a seed will germinate? **2.** How are seeds tested for percentage of germination? **3.** What is the meaning of digestion? **4.** How is starch changed into sugar? **5.** What is assimilation? **6.** From what part of the seed are the leaves formed? **7.** From what part is the root formed? **8.** What is a seedling? **9.** How are the materials in green plants and animals returned to the soil? See Fig. 17-22 on page 505 which will help you in answering this question.

F What are the different food substances?

There are six groups of foods. We say that *foods* are substances which supply materials for growth and repair. They also supply energy and regulate body actions. These six groups are: (1) *proteins;* (2) *fats and oils;* (3) *carbohydrates;* (4) *mineral salts;* (5) *vitamins;* and (6) *water.*

DEMONSTRATION

Put some cooked white of egg into a test tube and add a little dilute nitric acid. What color results? Pour off the nitric acid and add a little ammonia water. What change in color occurs? A yellow color with nitric acid, changing to an orange color with ammonia water, is a chemical test for protein.

Put a small piece of bacon on a piece of plain paper and leave it for a few hours. Result? The appearance of a translucent spot on the paper is an indication of the presence of a fat or oil.

Put a small amount of corn starch into a test tube with a little water. Pour in a few drops of iodine solution. Result? A dark blue, almost black, color indicates that starch is present.

Put a small amount of dextrose sugar or corn syrup into a test tube with a little water. Pour in some fresh Fehling's solution and heat the tube. Result? A change to yellow, green, or red color indicates the presence of a simple sugar.

Burn a bean seed in a crucible until the black color disappears. What remains of the bean? A gray ash indicates mineral matter, which cannot be burned.

Weigh a small piece of lettuce or celery. Heat it *gently* or let it stand for a day in a warm place. Weigh it again. Any loss of weight indicates loss of water by evaporation. A summary of these food tests is given in Fig. 17-24.

Try testing for the presence of the nutrients in some of the commoner food substances, such as bread, potato, apple, and meat. Record your results of one of them as on page 508, using bread as an example.

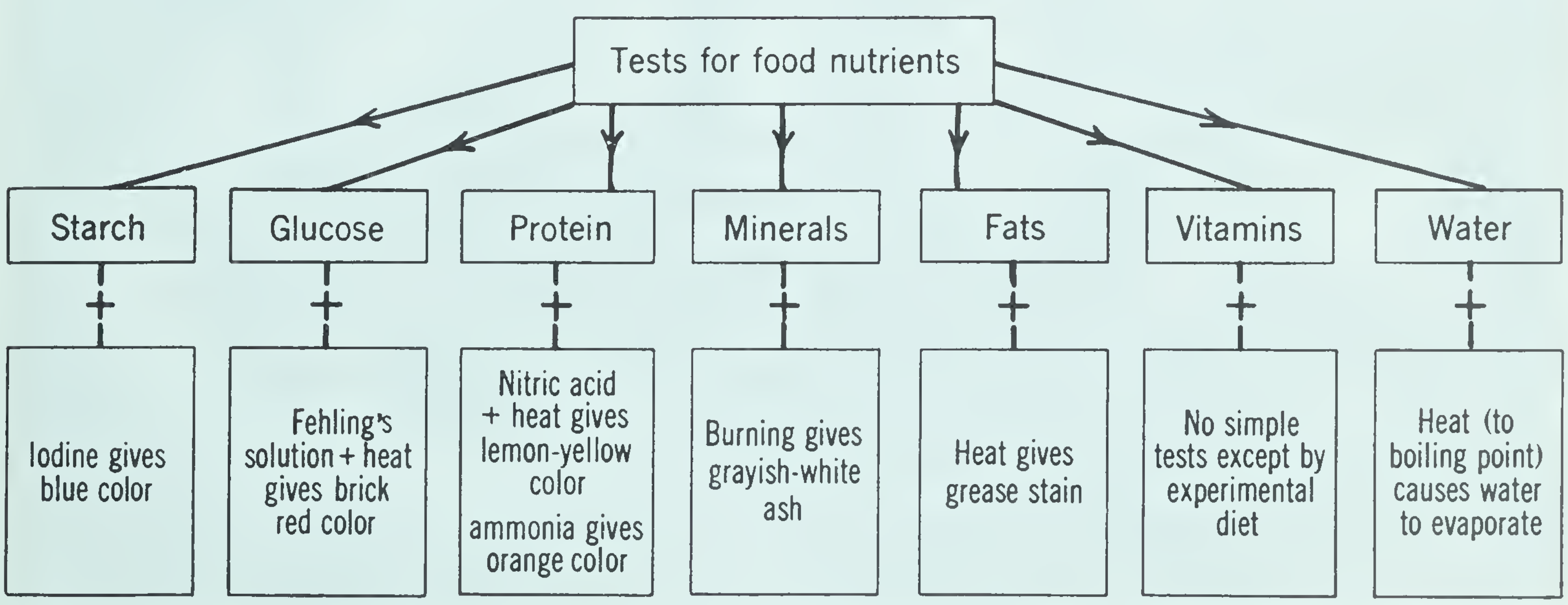


Fig. 17-24. This chart gives you a summary of common tests for the different groups of foods.

TESTS FOR SUBSTANCES IN BREAD

Test	Result	Conclusion
Proteins	Traces of yellow color	Traces of protein
Fat	No spots	No fats
Starch	Black color	Much starch
Sugar	Brick-red color	Some sugar
Minerals	Ashes	Minerals

Each type of food has its special use. Proteins aid in growth and repair. Foods which are rich in proteins are: eggs, peas, beans, cheese, and meat.

Fats are energy foods and supply fuel to the organism. Butter, oils, and fat in meats are examples. Can you name some others?

Carbohydrates are also energy foods, but contain less energy than fatty foods. Starches and sugars are the best examples of carbohydrates.

Mineral salts help to form the hard parts of plants, and bones and teeth in animals and man. Table salt is an example. Calcium in milk and iron in some of the vegetables are other important minerals.

Water dissolves foods and carries them to the cells.

Vitamins are necessary to keep living things healthy. They do not

Fig. 17-25. Minerals, found in green vegetables and certain fruits, are among the body-regulating substances necessary to good health.

supply energy nor do they aid in building protoplasm. But without them certain diseases, such as scurvy and rickets, develop in a short time. The green plant makes its own vitamins in its cells. So do certain animals. Too much cooking will often destroy vitamins. They are absent in foods which are highly refined, as white flour or sugar. Their best source is in fresh fruits and vegetables and in milk and butter.

REVIEW QUESTIONS

1. What is a food? **2.** What are the six classes of foods? **3.** What is the test for each? **4.** With what does each food supply the body? **5.** What foods are rich in carbohydrates, in proteins, in fats, in mineral matter, and in vitamins? **6.** How are vitamins in foods destroyed? **7.** What experiment can be performed to determine the percentage of water in a potato? **8.** What is the test for starch in a food? **9.** How could the weight of the minerals in a pint of milk be found by experiment?

G What is the economic importance of fungi?

There are many simple plants which are not green and contain no chlorophyll. Such plants are called *fungi* (*fun*-jy). They have no power to make their own food by photosynthesis and for this reason must obtain nourishment from either living or dead organisms. Over forty thousand species of fungi are known. Yeasts, bacteria, molds, mildews, rusts, smuts and mushrooms are some of the many groups. All of these plants reproduce, not by seeds, but by spores. A spore differs from a seed in that it is composed of only one cell.

A fungus which lives on or within a living plant or animal, and obtains its nourishment from it, is called a *parasite*. Smuts and rusts of cereal crops are examples of parasites. The plant upon which a parasite lives is called its *host*. Wheat is a host of rust, so is barberry. There is another group of fungi which secures its nourishment from dead bodies of plants or animals. Mushrooms and molds and bracket fungi and bacteria of decay are common examples. Such a plant is called a ***saprophyte*** (*sap*-ro-fight). It grows in rich earth, on rotting logs, on cheese and on bacon. Many of these fungi secrete enzymes which have the power to digest wood and other substances which we cannot digest. In this way they are able to get their supply of sugars and starches.

Some fungi, such as yeasts and molds and certain bacteria, are very helpful to man; other types are harmful, often destroying his food and crops and injuring his health.

Bacteria are the smallest known plants. They are the simplest form of fungi, each being composed of only one cell. There are numerous varieties of bacteria living in water, earth and air, and as parasites in plants and animals. So small are they that under a microscope that magnifies a thousand times in length, each appears

about as large as a period in ordinary print. According to their shape, bacteria are classified in three groups: the ***cocci*** (*kok*-sye), the ***bacilli*** (bass-*il*-eye) and the ***spirilla*** (spire-*il*-lah). The coccus is shaped like a sphere, the bacillus like a rod and the spirillum like a spiral. Many bacteria have hair-like structures which enable them to swim actively.

Bacteria may be small but they are mighty. They are mighty not only because of their destructive power but because of the valuable services they render to mankind.

Tuberculosis, pneumonia, tonsillitus and whooping cough are only a few of the human diseases caused by these parasites. They also cause many diseases of domesticated and wild animals and plants. Blackleg, one of the most destructive potato diseases in western Canada, is caused by bacteria.

On the other hand, many bacteria help to make crops possible and life enjoyable. The upper layers of moist soil are rich in bacterial life. Some of these cause the decay of plants and animals, thus not only acting as valuable scavengers, but enriching the soil and making continued life possible. Others change insoluble substances of the earth into soluble forms which can be used by plants as a source of food. Still others, called *nitrogen fixing bacteria*, take nitrogen from the air in the soil and make it over into plant food. Bacteria help in the preparation of dairy products and also add a desirable flavor. Certain bacteria play an important part in the manufacture of leather, the separation of the fibres of flax, the formation of vinegar from cider, and the purification of sewage. Of all living things none does a more important work in nature than bacteria.

The yeast plant is a very valuable fungus. Like bacteria, this plant consists of a single cell, but it is much larger, being about three-thousandths of an inch long. Yeast is often pressed

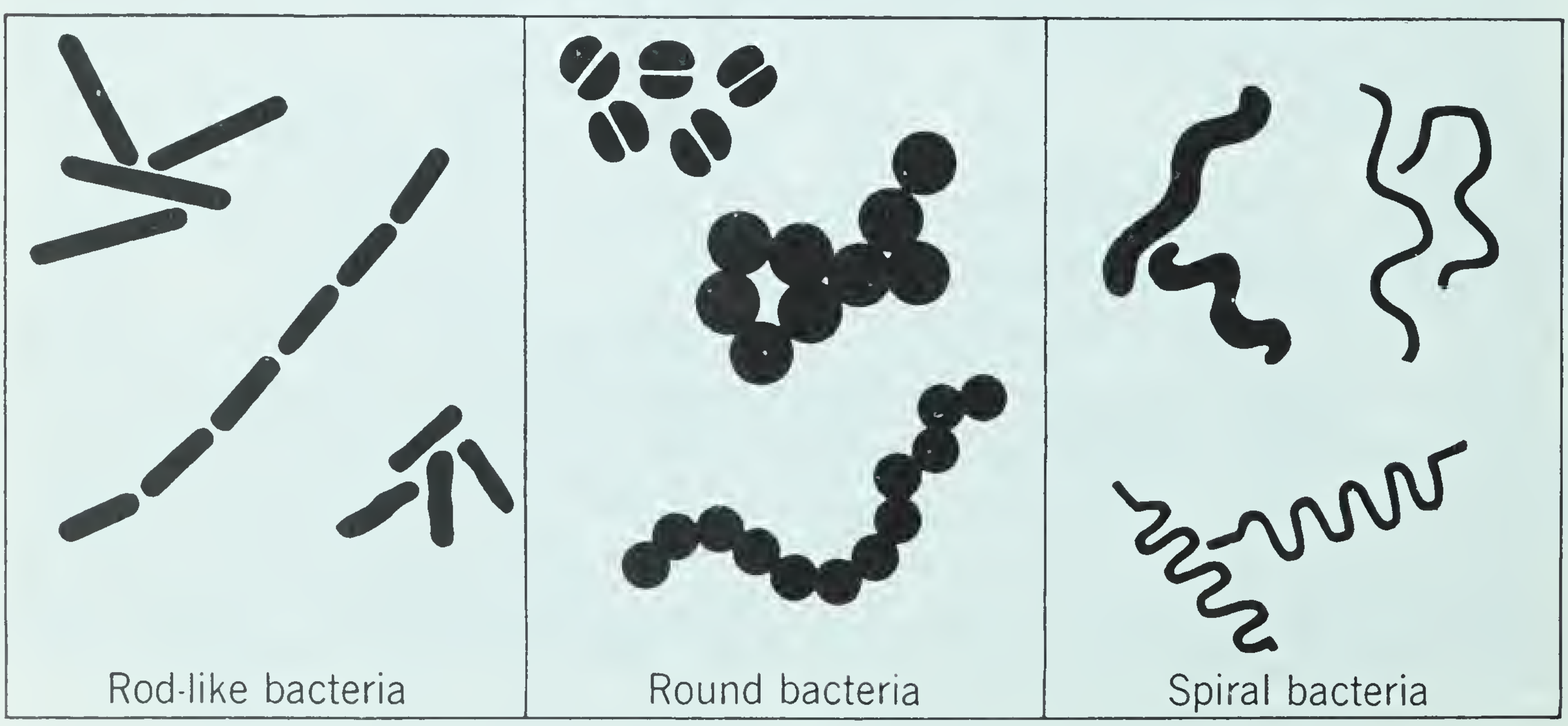


Fig. 17-26. These drawings show the three different forms of bacteria.

into cakes for the market. There are many different kinds, known by different names. Some of the "wild" species are used for making wine from grape juice; others make possible the manufacture of beer from sprouted barley; still others are used throughout the world for bread making. The yeast plant is much too small to be seen with the naked eye, but it may be studied easily if you are fortunate enough to have a microscope in the school.

PUPIL ACTIVITY

Place a small piece of yeast cake in some slightly sweetened water. Set aside in a warm place for a few hours. Examine some of the material under a microscope. Note the minute oval or nearly spherical cells, some joined together in chains. Find some cells which are budding. Make a sketch of their appearance.

DEMONSTRATION

Put some yeast in a glass or flask with molasses or any sweet fruit juice. Set aside in a warm place for a day or two. Results? Odor? Appearance?

Conduct the escaping gas into a vessel containing limewater and shake, or bubble some of the escaping gas through limewater as shown in the figure. Results? What gas is being given off?

Try the same experiment without putting yeast in the sweet solution. Result? Where do the yeast plants come from? How can you prove that there are wild yeast plants in your home?

You will notice that the sugar is changed by the living yeast plant into alcohol and carbon dioxide. This process is called *fermentation*.

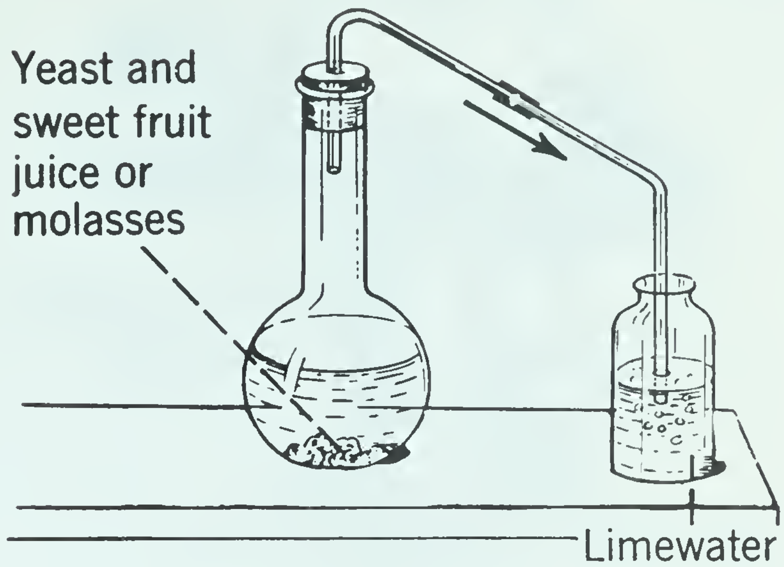


Fig. 17-27. Alcohol and carbon dioxide are produced by the fermentation of sugar.

In ordinary baking, yeast is mixed with the dough and left to "work" in a warm place. The yeast feeds on the flour, and fermentation occurs, forming a little alcohol and large quantities of carbon dioxide. The bubbles of gas are caught in the dough and unite to form the little holes we see in light bread. In the baking process the heat drives out the alcohol and makes the bubbles of gas expand. This enlarges the space in the dough and causes it to rise more.

The yeast plant may reproduce either by budding or by spores. During the former process an outgrowth develops on the side of the parent plant. The cell nucleus divides and part of it flows into the bud. Soon a wall forms between the parent and the bud, and the two cells separate.

Under unfavorable conditions, due to lack of food, the contents of each yeast plant may break up into three or four parts, each of which forms a *spore*. The spores may be dried without injury. They are very light and are carried about by the wind. Under favorable conditions of moisture and

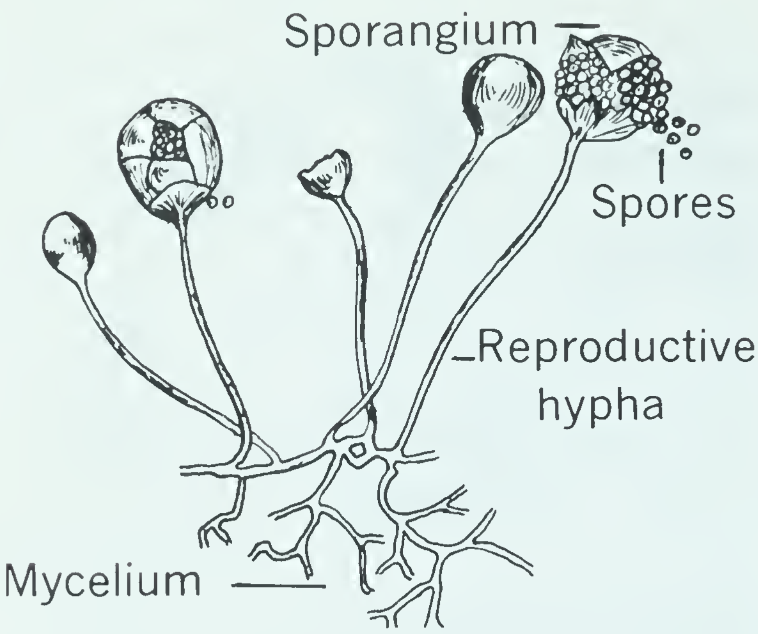


Fig. 17-28. This diagram shows what the mold on bread looks like when it is magnified.

heat, each spore may again develop into a yeast plant.

There are cases in which fermentation caused by yeast results in damage to jellies, preserves and canned fruit. The fact that this happens proves that the air about us is laden with the invisible spores of this tiny plant.

Molds are more complex plants than bacteria, and much larger. They are many-celled plants, composed of long filaments which often appear like a tangle of fine threads that usually extend deeply into the food substance on which the plants grow. The majority of molds are saprophytes. Some of them are white in color, others are green or pink or blue. Mold spores are everywhere in the air and on the soil, and will germinate as soon as they have the proper conditions of moisture and temperature and light. The most common fungus of this type is called the *bread*, or *black mold.*

PUPIL ACTIVITY

Expose a piece of bread to the air for a short time, or put it on the floor or undusted table, then dampen it and place it in a saucer. Put a tumbler over it and set it aside for a few days in a warm dark place. Do molds appear? What is their appearance when first examined? What difference do you notice a day or two later? Examine the mass of threads (mycelium) under a magnifying glass. Note the small black balls growing at the tips of upright filaments. Examine a portion of the mycelium under a microscope. Have any of the black balls (spore cases) broken open? Can you distinguish any individual spores that have escaped from their cases? Could these readily be blown about by the wind?

The body of a mold plant consists of a mass of threads called the ***mycelium*** (my-*see*-lee-um). The filaments which penetrate the host are called the ***nutritive hyphae*** (*high*-fee); those which grow upwards are called *reproductive hyphae.* At their tips spore cases develop. Each is called a ***sporangium*** (spoh-*ran*-gee-um). When mature each sporangium bursts open and scatters numerous spores which are so small that they cannot be seen with the naked eye. These spores are distributed everywhere by air currents. No piece of bread or any other food exposed to the air can escape them.

Some molds are injurious. They appear most commonly on cheese, bacon, bread, canned fruit and on clothing, leather and wood which have been exposed to dampness. Such molds are saprophytes, but there are some which are parasites, and are responsible for skin diseases, such as ringworm and athlete's foot. Others are

the cause of brown rots commonly found on apples and other fruit.

Most molds are inoffensive little plants which have important work to do in nature. Like bacteria, they help in the process of decay. Under a forest cover, leaves and twigs which fall to the ground are changed by them to a black top-soil, so familiar to us as leaf mold. Some molds give desirable flavors to cheeses. *Penicillin*, one of the modern "wonder drugs," is extracted from a certain kind of mold.

Mushrooms are a division of fleshy fungi. Some have queer shapes like umbrellas, clubs, spheres and brackets. They spring up overnight from April to late fall in the soils of damp woods, on decaying logs, among the grass in pastures and meadows and on the trunks of trees, both living and dead.

The mushrooms with which we are most familiar have umbrella-like caps borne at the end of a stalk. This structure is in reality only the fruiting body of the fungus. The rest of the plant consists of a system of branching threads which grow like a mass of white roots through the soil, manure, rotting log, or other material on which the fungi thrive. This vegetative part is used by commercial mushroom growers to plant their beds and is commonly called *mushroom spawn*. The fruiting body is furnished with *gills* arranged symmetrically around the stem on the underside of the cap. The spores, corresponding to the seeds of higher plants, are produced on the sides of these gills.

Since various mushrooms are often distinguished by the color of their spores, it is an interesting pastime to produce spore prints. The spores, produced in immense numbers, are always forcibly discharged into the air and generally borne away by air currents.

Fig. 17-29. This is a drawing of the Meadow Mushroom which is an edible variety.

PUPIL ACTIVITY

Cut the entire stem off a mushroom and lay the cap on white paper with the gills down. Cover the cap with a glass jar to protect it from air currents and leave it for a couple of hours. When the cap is removed it will be found that the spores have been deposited in such a way as to form a beautiful pattern of the gills. In this manner, spore prints are made. The color of the spore deposit can assist an expert to determine the species.

Some mushrooms are edible; others are deadly poisonous. For this reason one must learn a great deal about them before venturing to cook and eat them. By careful study we may learn to recognize a few of the edible sorts;

Fig. 17-30. The Morel is considered one of the most delicious of all mushrooms.

the deadly varieties are easily recognized. However, there is one, and only one, infallible sign that a mushroom is poisonous—the presence of a "cup" from which the stem grows. It is always just below the surface of the ground. Look for it. The two most deadly mushrooms of all, the *Destroying Angel* and the *Fly Agaric*, have stalks which rise from this "cup of death."

The safest rule for the beginner to follow is to gather only those mushrooms that he *knows* are edible, and discard all the others. As soon as possible, learn to recognize *Common Meadow Mushroom, Shaggy Mane* and *Morel*. They are delicious when cooked. That is a good start for a beginner. Shun, as poison, a brilliant cap of yellow, orange or even scarlet, studded with white or grayish spots.

There are many interesting fungi, closely related to the mushrooms, whose spores are not borne on gills. Among these are *bracket fungi, puffballs* and *earthstars*. The bracket fungi grow on stumps, logs, dead trees and even living trees. Their spores are borne in little pores on the underside of the bracket. There are many species of puffballs which are spherical or egg-shaped. Their spores are produced internally in numerous pockets. At maturity the walls break and the spores escape. So numerous are the spores that when a person steps on a mature plant the spores fly out in a smoke-like cloud. All puffballs, when young, are edible. The fungi known as earthstars are found growing close to the ground

Fig. 17-31. The Shaggy Mane mushroom is edible. How can you determine whether or not a mushroom is poisonous?

in mid-summer. They have a star-like base of from six to ten points, in the center of which is a spherical spore case about an inch in diameter with a hole on top. The young fruiting body is reddish-brown and is pointed at the tip. Some people gather these little fungi to cook and eat.

REVIEW QUESTIONS

1. What characteristics distinguish fungi from other plants? **2.** Distinguish between a parasite and a saprophyte. **3.** Into what three groups may bacteria be classified? **4.** What two products are driven off by yeast as its grows? **5.** In what two ways does yeast reproduce? **6.** How may molds be distinguished from other types of fungi? **7.** Name two edible and two poisonous species of mushrooms. **8.** Give reasons why bracket fungi and puffballs are not classified as mushrooms.

H What kinds of fungi do the most damage to farm crops?

Rusts are tiny parasitic members of the fungus group, responsible for serious plant diseases. Over two thousand kinds of rust are known. They are very destructive to cereal crops, fruits and many garden flowers, producing blotches of various colors on the leaves, stems and heads of grain. Each rust is caused by a different fungus. The hyphae, like those of the bread mold, penetrate the host and spread like numerous tentacles, injuring the plant tissues and causing enormous

Fig. 17-32. These wheat stems have been infected by rust. This fungus does untold damage to wheat crops.

losses in yield. Very severe stem rust epidemics swept the prairies in 1916, 1927, 1935 and 1954, with annual losses of about 100,000,000 bushels of wheat. Normally one rust attacks only one crop, or a few closely related crops. Thus *stem rust of wheat* attacks wheat and barley, but not oats or rye. None of the cereal rusts attacks flax which has its own rust. The most serious rusts on the prairie are leaf and stem rust of wheat. Stem rust produces large brownish-red blotches, called ***pustules*** (*puhs*-tules), not only on the stems but also on the leaves and heads. *Leaf rust* produces small, round, orange-red pustules, mostly on the leaves. Not only do these rusts greatly reduce the yield, but the flour milled from such grains is of inferior quality.

Wheat stem rust may live on two

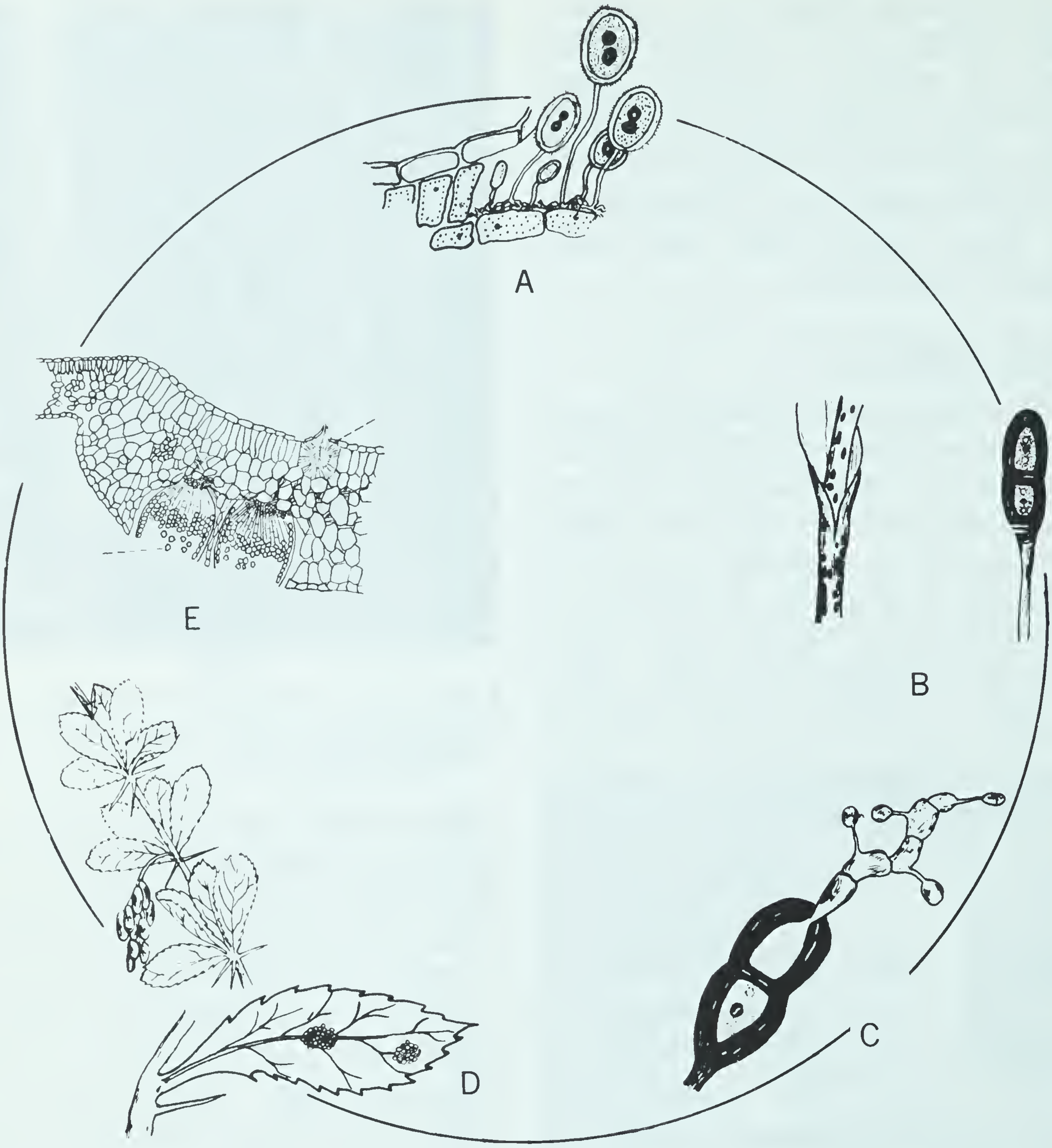


Fig. 17-33. During its life cycle the wheat stem rust produces five kinds of spores. **A** shows the spores of the red stage of rust breaking through the leaf epidermis. **B** shows a wheat stalk infected with black rust spores such as that shown in enlargement at the right. **C** is a black, or resting spore, germinating to form small spores, or sporidia, by means of which the fungus spreads from wheat straw to barberry bushes in the spring. **D** shows a branch of Common Barberry and the underside of a single leaf showing groups of cluster cups. **E** is a cross section of barberry leaf, showing a pycnium, two cluster cups, and cluster cup spores.

distinctly different host plants: wheat and Common Barberry. During its complete cycle it produces five kinds of spores of which the *red rust spores* are the most common. In the summer they are carried by the wind, and like an invisible dust storm fall on the young crops. Should the weather be warm and wet, with frequent showers and heavy dews, they will immediately germinate and start to develop. In about ten days the fungi will mature

and more red spores will be carried to other fields.

As the wheat plant approaches maturity, the pustules on the leaves and stems become dark in color. Here, two-celled and thick-walled *black spores* appear instead of the red ones. These cannot attack wheat, but unlike the red spores, will winter-over in western Canada. In the spring they will germinate, each producing four very small, almost colorless, *spring spores*. These may be scattered far and wide by the wind but they will germinate only on a small shrub called the *Common Barberry*. The process is quite complex and we will not go into details here. The barberry leaf soon becomes thickened at the area where the spore adheres. On the upper side of the leaf there soon develops flask-shaped structures, called ***pycnia*** (*pik*-nee-ah) (see Fig. 17-33) and within them *pycniospores*. There now develops on the underside of the leaf cup-shaped depressions which become filled with yellowish spores, commonly called *cluster-cup spores* ***aeciospores*** (*ee*-see-oh-spores). Should these be carried by the wind to wheat plants they will produce another crop of red spores. And so the cycle is completed.

In the great central plain of western Canada there are only two possible sources of stem rust which may cause infestations on grain plants. Due to the severity of our winters, few red rust spores survive. The black spores are not destroyed by the cold weather but the spring spores, produced by them, have no chance to develop, since there are no Common Barberry shrubs in Manitoba, Saskatchewan or Alberta. They are not native to this area, and the few that were introduced as ornamental shrubs have been eradicated. Unfortunately the barberry still grows quite extensively to the south of our border, but even at that, the cluster-cup spores carried here by the winds are not considered an important factor in spreading stem rust. The cause of the greatest infestations are due to red spores, untold millions of which are carried to western Canada from the northern states. They originate in Texas and Mexico where they over-winter on winter wheat and some grasses. In the spring the red spores are blown north in stages from wheat crop to wheat crop. By June or early July they reach southern Manitoba and south-eastern Saskatchewan. Our first crop of red spores develop in this area, and succeeding crops spread gradually towards the west and north. This is the reason why less severe infestations usually occur in the north and northwest prairie regions.

There are many races of wheat stem rust. Just as there are varieties of wheat and oats and barley, there are also varieties or races of rust. These races cannot be distinguished by their appearance but only by their reaction on standard varieties of wheat, twelve of which are used the world over. Marquis, the standard variety for many years, was severely attacked by a stem rust known as Race 56, resulting in widespread losses during several severe epidemics over a period of twenty years. Plant breeders and plant pathologists in Canada and the United

States were able to produce and distribute at least five new wheat varieties that were resistant to Race 56, 36, 21 and 38. By 1935, rust resistant wheats covered a large portion of the prairies. For a time, *Thatcher, Apex, Regent* and *Renown* seemed to be the solution to the problem. It has been estimated that these rust-resistant varieties have saved prairie farmers an average of more than 40,000,000 bushels of wheat per year.

In the period from 1939 to 1950, stem rust was almost unknown on the Canadian prairies, but a new race called 15B, which had first been detected in 1939, invaded the prairies in epidemic proportions in 1950. Since then its rapid spread has threatened the entire wheat production in western Canada. All the rust-resistant varieties mentioned, as well as the newer ones, *Lee* and *Redman*, proved susceptible to 15B. To fight this menace, *Selkirk* was developed at the Cereal Breeding Laboratory at Winnipeg, and after several years of selection was distributed to farmers in western Canada in 1953 and 1954. This helped to relieve the situation. But soon Selkirk proved susceptible to another new race of stem rust, called $15B_3$, and so it seems likely that the new wheat will last for only a few years as a rust-resistant variety.

The battle is not yet over. Plant breeders must never relinquish their researches and must always continue to develop new varieties, resistant to new races which will appear from time to time, even though it takes from five to ten years to develop a new variety of high quality wheat. The old favorites, *Marquis* and *Thatcher*, are now being crossed with an Ethiopian variety which is highly resistant to 15B rust. The first cross will be back-crossed several times with the Canadian parents to give it a high standard of milling quality. In the future it is hoped that a variety immune to all races of rust will be developed.

There are three methods recommended for the control of stem rust in western Canada.

1. Seed only varieties of grain which are recommended as being resistant to the disease.
2. Sow early maturing resistant varieties.
3. Sow the grain as early as possible.

REVIEW QUESTIONS

1. Name two of the most damaging types of grain rusts. **2.** What is the nature of damage caused by rust on grain? **3.** Tell something about the extent of damage caused by stem rust of wheat. **4.** What are the causes of rust infestations on the Canadian prairie? **5.** Explain what is meant by races of stem rust. **6.** What steps are being taken to prevent loss of grain crops by rust? **7.** Name several varieties of wheat that are, or were, resistant to stem rust. **8.** Why will it be necessary for plant breeders to continue to develop varieties of grain that are rust resistant?

Smut fungi are also destructive parasites on many cultivated crops. Of particular interest are their attacks on wheat, oats, barley and corn. During their development the smut fungi, like those of rusts, consist of hyphae which

penetrate tissues and absorb nourishment. The network of hyphae is collectively called the mycelium and is the main part of the plant body of a fungus. After a period of growth in the host tissues, the mycelium produces numerous spores which appear as black powdery masses, sometimes on leaves and stems, but more often on the heads of the grain. Although about fifty species of smut fungi are known to occur in Canada, about twenty species attack cereal forage crops and may cause considerable loss, if proper control measures are neglected. As an example, the combined loss of wheat, oats and barley, in Manitoba alone, in 1948, was in excess of four million dollars. Smut diseases are still prevalent and destructive, but the losses caused by them at present are small in comparison to those experienced before effective seed disinfectants were developed.

The cereal smuts may be divided into two main types. In one, the spore is carried over winter *on the seed* and in the other it is carried *in the seed*. Originally, these two types were called *covered smut* and *loose smut*, but these names are rather confusing, since the loose smut of oats as well as the false loose smut of barley, belong to the same type as the covered smuts of wheat and oats—that is, the type in which the spore over-winters on the seed. It is comparatively easy to destroy smuts which are carried on the seed, but difficult if spores are lodged within the seed.

Covered smut of wheat is commonly called bunt or stinking smut. The latter name is given because of the foul-smelling spores produced in smut balls, which replace the grains in the heads of wheat. When wheat is threshed a large proportion of the bunt balls is broken and many of the spores, thus set free, adhere to the grains of wheat.

Fig. 17-34. The wheat stalks on the right have been infected by bunt, or covered smut. The one on the left is a healthy head, the kernels well filled out.

The seeded wheat sprouts at the same time as the spores on it. The hyphae easily penetrate the sprouted grain and the mycelium develops like a cancer within the plant, as it grows from a seedling to maturity. When the head forms, the mycelium is there preparing for its fruiting stage. Soon the spores develop within many of the seed coats and form what we have called bunt balls. This disease is called covered smut since the spores are hidden from view.

Fig. 17-35. This photograph shows how wheat is affected when attacked by loose smut. Instead of well-grown stalks like that at the left, the farmer has withered, stunted plants covered with masses of black spores.

Covered smut of oats is hidden in a similar manner, but loose smut of oats destroys the entire head, leaving only the central stem and appearing as a sooty mass of numerous spores.

The true loose smuts are those whose spores are carried in the seed. Our most common types are the loose smuts of wheat and barley. The spores of these fungi are air-borne at the very time when the healthy grain plants are in bloom. They germinate on the stigmas of the flowers, and the hyphae penetrate down to the embryo seed forming a mycelium mat within it. This remains hidden in a dormant state until the seed germinates. It then becomes active and grows within the plant as it develops. After the head is formed the disease takes over, destroying the developing flowers and replacing them with conspicuous masses of black spores. In a few days these are blown away, leaving a bare flower-stem instead of a normal healthy head of wheat or barley.

Smuts which are carried on the seed are controlled by the use of *fungicides* (*fun*-ji-sides). There are many of these on the market with various trade names. Some of them, including *Leytosan* and *Ceresan*, contain poisonous mercury salts, and are called mercury dusts. There are other fungicides containing mercury which are sold in liquid form. *Leytosol* is an example. Still others contain no mercury compounds. Among these, in dust form, are *No Bunt* and *Bunt-no-more*. These

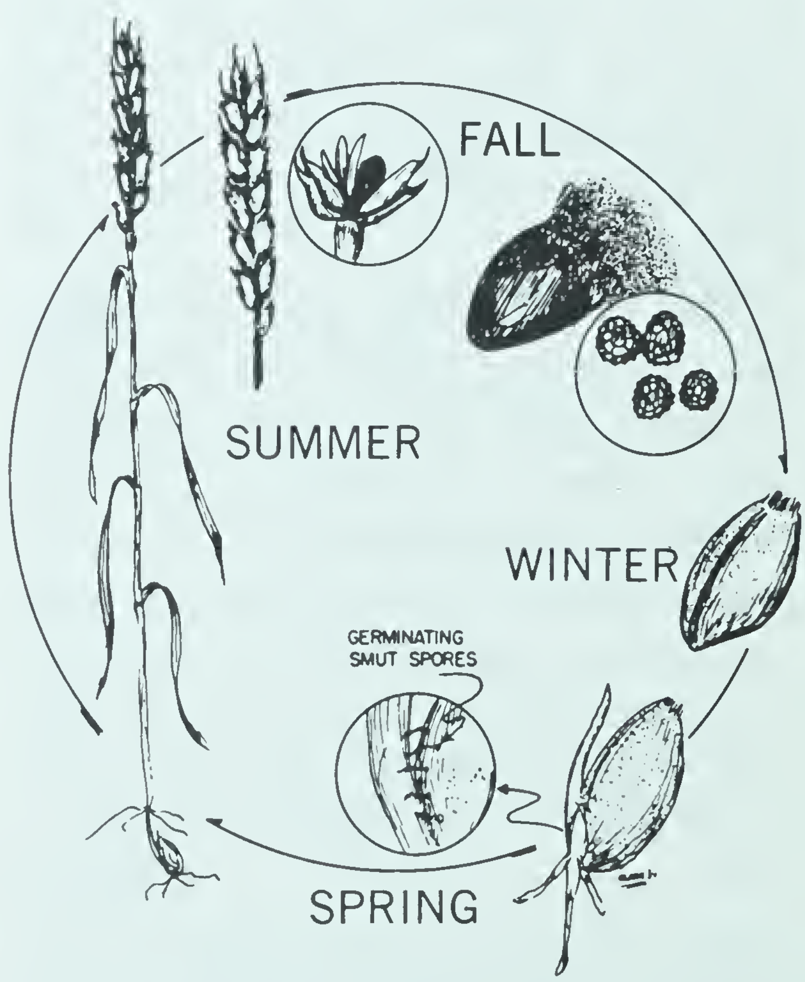


Fig. 17-36. This chart illustrates the life cycle of the bunt of wheat from the time the smut spores germinate on the seeded wheat until they once again repose on a grain of wheat waiting for favorable conditions to start them growing.

give good control of bunt but are not so effective on covered and loose smuts of oats.

Of particular interest are mixtures which have been prepared for the control of both wireworms and smut at the same time. Among these dual purpose treatments are *Mergamma C* and *Mercury-lindane*. Lindane has proved to be an effective compound for the destruction of wireworms.

Since fungicides which contain mercury are very poisonous, strict precautions must be observed. The proper machine should be used for mixing the fungicide with the grain; masks should be worn when treating seed; the machine should be so placed that the wind will blow the dust or fumes away from the operator; livestock and children should be kept away from treated grain.

Smuts which are carried in the seed, such as loose smut of wheat, require either a hot water or a cool water treatment. The hot water method is rather complicated and special machines have been made for the purpose. The seed is first soaked for five hours in water at 70° F. It is then transferred to bags and dipped for eleven minutes in water constantly held at 129° F. After that, it is removed and allowed to cool off in cold water.

In the cool water method the seed may be soaked in a solution of a compound called *Spergon* at a temperature of 75° F for 48 hours. Following either of these treatments the seed must be dried thoroughly. (These water treatment methods are not very practicable for use by most farmers.)

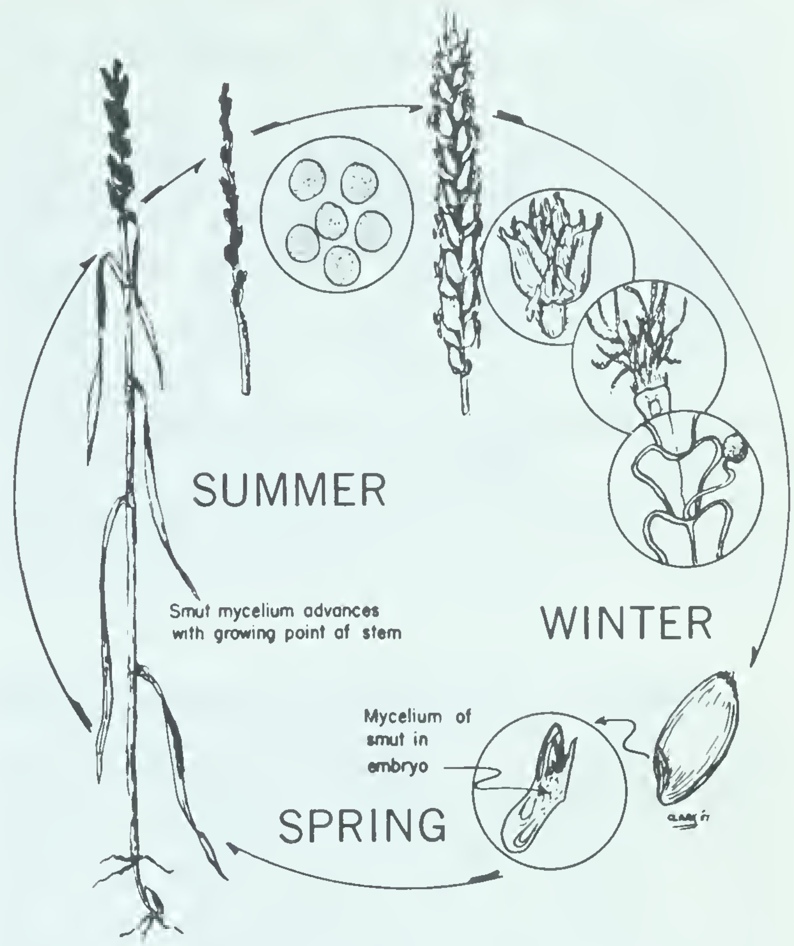


Fig. 17-37. This chart illustrates the life cycle of the loose smut of wheat.

Damage to crops by smut may be curtailed by sowing smut-resistant grain varieties or by using smut-free seed. Unfortunately smut-resistant varieties, which have been developed, may be susceptible to rust or may be undesirable in other ways. Renown, Regent and Redman wheats are all resistant to bunt. Thatcher is resistant to loose smut. Selkirk is resistant to both bunt and loose smut. All of the recommended varieties of oats and barley are susceptible to either loose smut or covered smut or both.

Farmers of the western grain lands, wherever possible, solve the problem by purchasing smut-free grains for seed. Either registered or certified seed is practically free of smuts.

REVIEW QUESTIONS

1. What is meant by mycelium of a fungus? **2.** Distinguish between the two

main types of smuts. **3.** Why are these types not simply called covered smut and loose smut? **4.** What are bunt balls? **5.** Why is bunt called covered smut? **6.** How may the presence of loose smut of oats be detected? **7.** What are fungicides? **8.** What types of smut are controlled by fungicides? **9.** Name three common fungicides used for the control of smut. **10.** Name a variety of wheat that is resistant to both bunt and loose smut.

Extensive damage is done to cereal and other grass crops by a group of parasitic fungi called rootrots. These are diseases of the root system and lower portion of the stems, just as rusts and smuts are diseases of the leaves and head. It is difficult to estimate the damage caused each year in the three prairie provinces, as it varies each season according to the type of the soil as well as moisture conditions. There is no doubt, however, that root diseases cause considerable loss due to lower grades and smaller yields. There are three types, *Common Rootrot, Take-all Rootrot* and *Browning Rootrot.*

Common Rootrot is the most prevalent root disease of wheat, oats, barley and rye. The fungus which causes the disease over-winters on the surface of the soil, particularly among the straw and other trash. It attacks the seedlings shortly after germination and many are killed before reaching the surface of the soil. Brown discolorations of the roots, crowns and stem bases soon appear in the growing crop. As the crop approaches maturity, bleached, ripened and dead plants may be found in the field among the green ones.

Damage may be lessened by using the best seed obtainable, by early seeding, and by the application of suitable commercial fertilizers to strengthen the plants, enabling them to resist the disease. The attacks are also rendered less severe by plowing under the surface trash cover. This procedure, however, is not advisable in areas where there may be danger of soil drifting.

Take-all Rootroot may attack both wheat and barley but, in western Canada, it is principally a disease of wheat. It seldom occurs on the open prairie but does great damage in the parklands and wooded areas where dark brown and black soils predominate. It is most prevalent in the second and third crops after breaking, frequently appearing in fairly large patches. Here the plants are stunted, some of the leaves are bleached and the roots and crowns are blackened and partly rotted. In some cases either the heads are not formed, or, where they are, much of the grain is shrunken.

Since the roots are decayed and brittle, plants may be pulled easily from the soil. Many die prematurely. The disease also appears on new breaking or in older fields but here the infected plants may be widely separated.

Since the fungus passes part of its life cycle on the stubble, it is thought that a trash cover, now considered so important to successful farming practice, may be a cause of increased damage.

To check the rootrot it is recom-

mended that wheat should not be grown after wheat. Instead a suitable crop rotation should be adhered to, such as wheat—oats—wheat—fallow, followed by another suitable sequence of crops recommended for the district.

REVIEW QUESTIONS

1. How does Common Rootrot fungus gain access to the plant? **2.** What are some common indications of the disease in growing grain crops? **3.** How may this disease be controlled, or made less severe? **4.** In which soil zone does Take-all Rootrot do the greatest damage? **5.** In what type of a field of wheat is the damage most extensive? **6.** How may the presence of this disease be detected in the growing wheat crop?

Several kinds of parasitic fungi, including bacteria, are responsible for diseases in potato tubers. Those which cause the greatest damage in western Canada are *Common Scab, Blackleg, Rhizoctonia* (*Rye*-zoc-toe-nea) and *Bacterial Ring-rot.*

Scab is the most common potato disease. The fungus which causes it

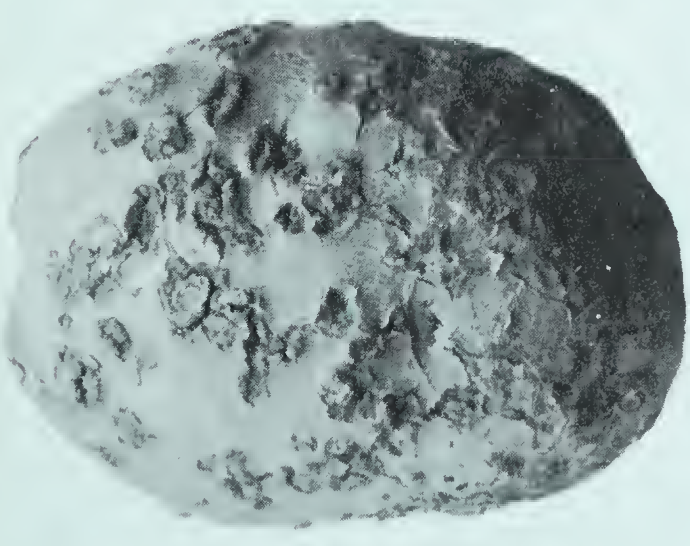


Fig. 17-38. The corky spots on this potato were caused by a fungus called Common Scab.

Fig. 17-39. A cross-section of a potato which has been attacked by Blackleg will look like this.

winters either on the skin of the tubers or in the soil. Rough, corky spots appear on the potatoes. Their presence seems to have little effect on either the yield or the quality. The scabs, however, do give the potato an undesirable appearance which is not acceptable to the housewife. The result is that such potatoes cannot be marketed easily. A variety, called *Netted Gem*, is resistant to scab, but unfortunately this species is not suitable for growing in the drier prairie regions.

Blackleg is one of the most destructive potato diseases. It actually rots portions of the tubers, making them unfit for consumption. It may be detected in the growing crop by the presence of bright yellow foliage, stunted plants, which are blackened at the base of the stems, and by the fact that plants may be pulled easily from the ground. The bacteria, which are responsible for the disease, winter in the tubers, eventually forming a soft rot at the stem end. The rot spreads upward causing the blackened appearance, mentioned above, at the base of the stem.

Fig. 17-40. The Rhizoctonia fungus causes black spots to appear on the potato-host.

Rhizoctonia, commonly called Black Scurf, may be detected by the presence of numerous black spots on the skin of the tuber. Each spot is a fungus body. In the growing crop, the disease may sometimes be recognized by the appearance of aerial tubers, caused by injury to the base of the stem. The fungus remains in the soil over winter and may contaminate the potato cuttings soon after they are planted. Infection is greater in damp, cold soils.

Bacterial Ring-rot is a highly infectious disease which has gained considerable headway on the prairies. In the growing crop, the presence of wilted and yellow plants with curled leaves is an indication of the disease. Potatoes with a brown rot at the stem ends should be further examined by making a cross section near that end. When a potato is cut in half, the presence of a light brown, cheesy ring is further indication that the cause of the infection may be ring-rot. All such tubers should be discarded, and the rest of the potatoes, as well as cutting knives, planting machinery and bags, should be disinfected with formalin at a concentration of one pint to twenty-five gallons of water.

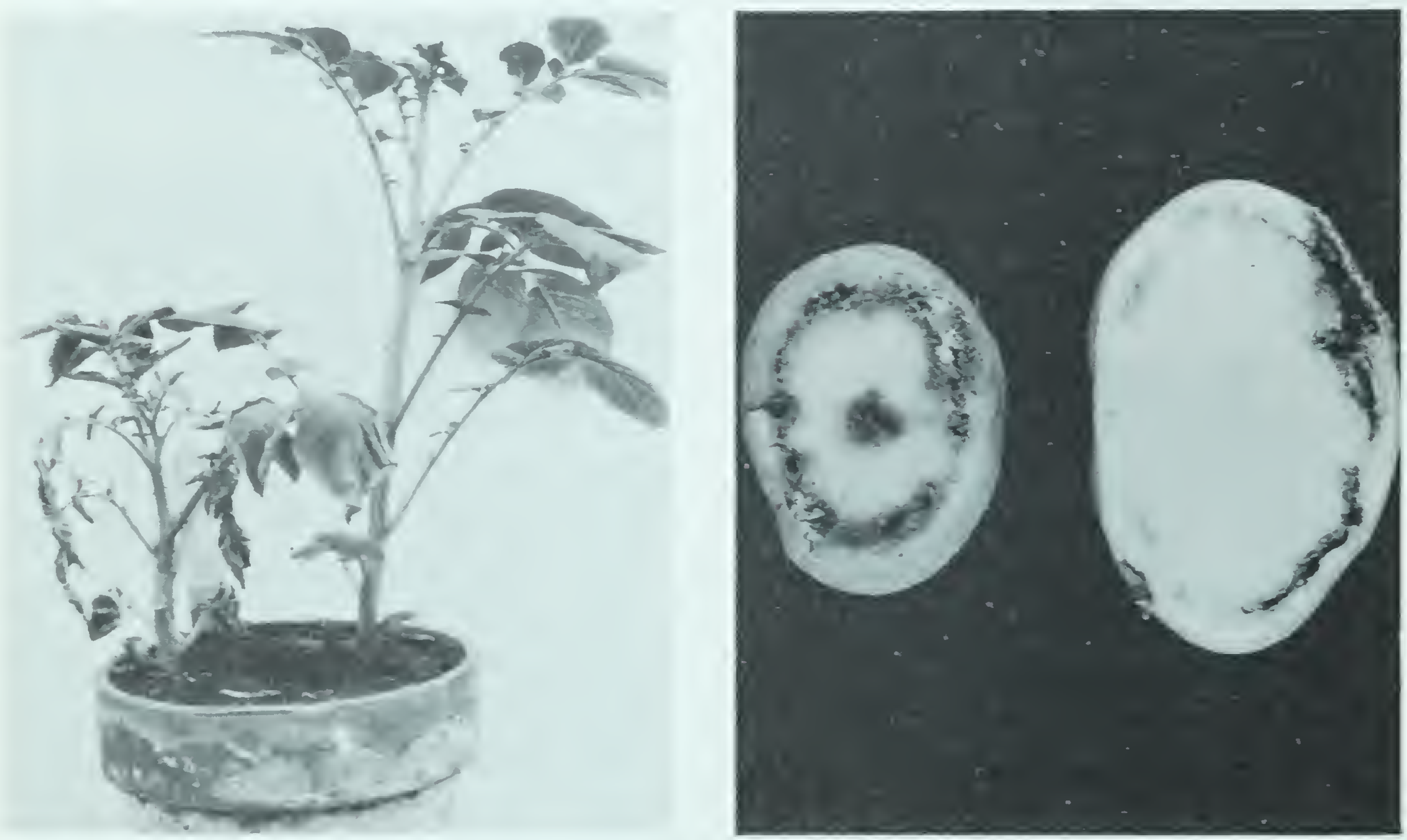


Fig. 17-41. Bacterial Ring-rot causes potato plants to wilt and turn yellow, like the plant at the left. When the potatoes are cut through a distinct ring of diseased cells may be seen.

Damage to potato tubers by fungi may generally be avoided, if the following precautions are taken: (1) It is best to use certified seed, but in any case use only tubers which are apparently disease free. (2) Discard tubers if cuttings show the presence of internal discoloration. (3) Do not plant cuttings from tubers that have been cut or otherwise damaged during digging or storage. (4) Do not plant potatoes on the same soil more than once in four years. (5) Avoid old garden soils and those which have been freshly manured. (6) If it is suspected that Bacterial Ring-rot may be present, the disinfecting procedures mentioned before should be strictly adhered to. (7) *Semesan Bel* is a recommended fungicide for the treatment of Common Scab and Blackleg. Soak the cuttings for two minutes in a solution of one pound of the chemical to six gallons of water.

Only limited success may be expected in the control of disease by seed treatment because some fungi live only in the soil (Rhizoctonia); others live only in the tuber (Bacterial Ring-rot); some live on the tuber (Blackleg and Common Scab), and others live both on the tuber and in the soil (Common Scab). (8) Inspect the crop during the summer and remove and destroy diseased plants.

REVIEW QUESTIONS

1. How may the following potato diseases be detected by an examination of the tubers: (1) Bacterial Ringrot? (2) Blackleg? (3) Common Scab? (4) Rhizoctonia? **2.** How may the following potato diseases be detected in the growing crop: (1) Rhizoctonia? (2) Blackleg? **3.** If it is suspected that some potato cuttings, ready for planting, may be infected with Bacterial Ring-rot, what special precautions should be observed?

QUESTIONS FOR REVIEW AND DISCUSSION

1. Why do we say the green plant is the source of all our foods?
2. What is photosynthesis? Under what conditions does it occur? What by-product is set free? Why will plants not grow in a dark room?
3. Describe the principal organs of a plant and the function of each.
4. How does a plant get water and minerals from the soil? What use does it make of these?
5. How is a seed formed? Under what conditions does it germinate?
6. What are the six groups of food nutrients? What is the test for each? What is the purpose of each as a food?

7. Name five ways in which bacteria are helpful to man. Tell how some molds are injurious to man.

8. Outline briefly the life cycle of stem rust of wheat, naming the five kinds of spores produced during the cycle, and tell what the host is in each stage.

9. Since the spores of Loose Smut of wheat are buried within the seed, what method is used for the control of this disease?

10. What general methods should be applied to reduce losses by potato diseases?

SPECIAL REPORTS AND PROBLEMS

1. The different materials we get from trees, flax, and corn.
2. The part the microscope has taken in the study of plants.
3. Make a collection of grain heads affected by (1) Loose Smut and (2) Covered Smut.
4. Make a collection of the stems of various grains infected by rust.
5. What manufacturing industries in your community are dependent on plants? What plants do they use?
6. The discovery of vitamins.

TESTING THE PURPOSES OF THIS UNIT

1. Define or give the meaning of each of the following words or terms: cell, protoplasm, chlorophyll, carbohydrates, photosynthesis, osmosis, soil minerals, root hairs, flower, seed, fruit, pollination, cross-pollination, self-pollination, germination, food nutrients, digestion, assimilation, plant diseases, saprophyte, fungus, fermentation.

2. In what ways are plants dependent on animals? Animals on plants? Can one exist without the other?

3. In growing crops, what does a successful farmer or gardener need to know about soil fertility, seeds, growth of plants, and nature of plant diseases?

4. What plans need to be followed in preventing the spread of plant diseases?

5. Why may only a limited success be expected in the control of potato diseases by seed treatment?

6. What two methods, other than by the use of fungicides, are employed by farmers to lessen smut damage?

7. Outline the life cycle of Loose Smut of wheat.

8. List the distinguishing characteristics of various poisonous varieties of mushrooms.

The old

EXCEPT FOR GENERAL OBSERVATIONS, MAN MADE LITTLE progress in the study of plants until the invention of the microscope. This instrument was crude at first and did not magnify enough to make it possible to see cells clearly. It was rapidly improved, and the discovery of the cell structure of plants was the beginning of many other important discoveries.

The new

MAN HAS LEARNED A GREAT DEAL ABOUT WHAT PLANTS WILL do under different conditions. But he still does not understand how certain activities go on in the plant. Osmosis, photosynthesis, digestion, respiration, and fertilization do occur, but there is at present no complete explanation for any of them.

Man has not actually *created* new plants. What he has done is to *develop* new varieties of plants from those already known. He has made the environmental conditions suitable for the plants, so that they react favorably. In artificial pollination, man transfers the pollen from the stamen of one variety of plant to the pistil of another. He cannot at first predict accurately what changes will occur under such conditions. He must wait and see what features the plants show. Sometimes these experiments are successful and sometimes they are flat failures. If the new variety is desirable, it can be repeated later with certainty.

There is a great need today for better quality plants which produce larger yields and higher food content. There is also a need for plants which are resistant to diseases. Plant breeders, using modern methods, are continually trying to develop new varieties which have these better traits.

UNIT 18

DISCOVERY AND PROGRESS

How has man learned to control and use insects?

AT first, ancient man did not concern himself a great deal about insects. He knew nothing about the spread of disease germs. Insects were a mere annoyance with their bites and stings.

But when man began to domesticate plants and animals, he was faced with the problem of protecting them from harmful insects. He was forced to take the first steps in destroying insect life. The unceasing battle, insects versus man, had begun.

From time to time in ancient writings we find reference to insects and the harm caused by them. In the Bible (*Exodus 10*) we read about the great locust plagues, "For they (locusts) covered the face of the whole earth . . .

there remained not any green thing in the trees or in the herbs of the field, through all the land of Egypt."

Many scientists have contributed to our knowledge of insect life. Langstroth, Fabre, Comstock, and Lazear, receive special recognition here, but there are many others, who, by their work and writings, have encouraged further study and research.

Lorenzo Langstroth (1810-1895) was a teacher. His hobby was bee-keeping and he made a special study of bees. He was an interesting writer and is known for his book *The Hive and the Honey Bee*. Langstroth, however, is remembered mainly for his invention of the movable frame used in bee-keeping today.

Jean Henri Fabre (1823-1915) was born in France. He is noted more for his clear, interesting writings than for the accuracy of his scientific observations. Fabre wrote ten volumes on insects, describing their activities in their natural surroundings. Many of his books have been translated into English.

One of the best known books in natural science is *A Manual for the Study of Insects*. This book was written by John Henry Comstock, assisted by his wife, Anna. Comstock (1849-1931) was an outstanding authority on insect study. He wrote with great scientific accuracy, in an entertaining manner, attempting to make the study of insects as popular as the study of birds and flowers.

Lazear is famous for his investigations into the spread of the disease called yellow fever. By 1900, it had become evident to scientists that yellow fever was in some way related to the activities of a certain mosquito, *Aedes calopus*. The mosquitoes were allowed to suck the blood of a yellow fever patient and were then placed on healthy people. Lazear was one who volunteered to expose himself to infection by this means. As a result, he contracted yellow fever and died within a short time. However, his studies aided other scientists to learn how to control this dread disease.

No doubt you have read that it would have been impossible to construct the Panama Canal without first controlling the fever-carrying mosquitoes. This fact is well known, and emphasizes the importance of insects. Sanitary engineers, under Major-General Gorgas, worked diligently, draining swamps, digging ditches, cutting grass and brush. Millions of dollars were spent in insect control before construction of this great project could proceed in safety.

As the population of the world continues to increase, man must constantly strive to produce more food. He must study all the factors that will aid him in doing this. Insect pests destroy thousands of acres of crop each year. Therefore, insect control must occupy the attention of scientists everywhere.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What are the main characteristics of insects? **2.** How are insects classified? **3.** In what ways may insects avoid their enemies? **4.** In what ways may insects be useful to man? **5.** In what ways may insects be harmful? **6.** What insects cause the greatest losses to prairie gardens? **7.** How do we deal with insects that destroy our field crops? **8.** What is the main principle in regard to poisoning insects? **9.** How are bees useful to man?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

aphid . . . . (*ay*-fid), a form of plant lice.

apiary . . . . (*ay*-pi-airy), a collection of hives, or colonies of bees kept for their honey.

exoskeleton . . . . the hard outer covering of an organism.

fumigation . . . . the act of applying smoke, vapor, or gas, to destroy insects or to disinfect clothing and other articles.

insecticide . . . . a chemical preparation in form of liquid or powder used to deter or destroy insects.

larva . . . . the caterpillar or grub state of an insect; the first stage after the egg.

mimicry . . . . (*mim*-ik-ree), a resemblance of one organism to another.

nymph . . . . (nimf), a young insect that resembles the adult in most of its characteristics.

protective coloration the development of a color scheme by an animal to permit it to harmonize with the surroundings.

pupa . . . . the dormant or resting stage of the life cycle of an insect.

A How are insects recognized and classified?

Insects have certain general characteristics that distinguish them from other forms of animal life. Thus, the typical adult insect has a hard protective covering known as an outer-skeleton or *exoskeleton*. This is jointed to permit free movement of all parts of the body. All insects have *six legs, one pair of antennae* and *breathing tubes* that have openings along the sides of the body. The body itself has three distinct parts: *head, thorax* (*tho*-rax) and *abdomen* (*ab*-dohmen).

There are several methods of classifying insects. For purposes of control a simple classification is based on the kinds of mouth parts. Some insects have *biting mouth parts* which they use for biting and chewing the leaves, stems, and rootlets of plants. Other insects have *sucking mouth parts* that enable them to penetrate the surfaces of leaves, stems, and buds, to suck the juices from within.

Another broad method of classification is according to the way an insect develops. We use the term ***metamorphosis*** (meta-*mor*-foh-sis) to indicate the changes in form that an insect undergoes during its life cycle from the egg to the adult. Many insects, after hatching from an egg, pass through three distinct stages: *larva, pupa,* and *adult*. The larvae are usually soft-bodied, worm-like, and may be referred to as worms, caterpillars or, simply, grubs. The pupa stage is often called the resting stage because no activity may be seen. But we must remember that great changes are going on inside the insect's body, before it emerges as a fully-developed adult. Insects that develop in three stages, after the egg, are said to have a *complete metamorphosis.* Ants, bees, moths, butterflies, and certain other insects, undergo a

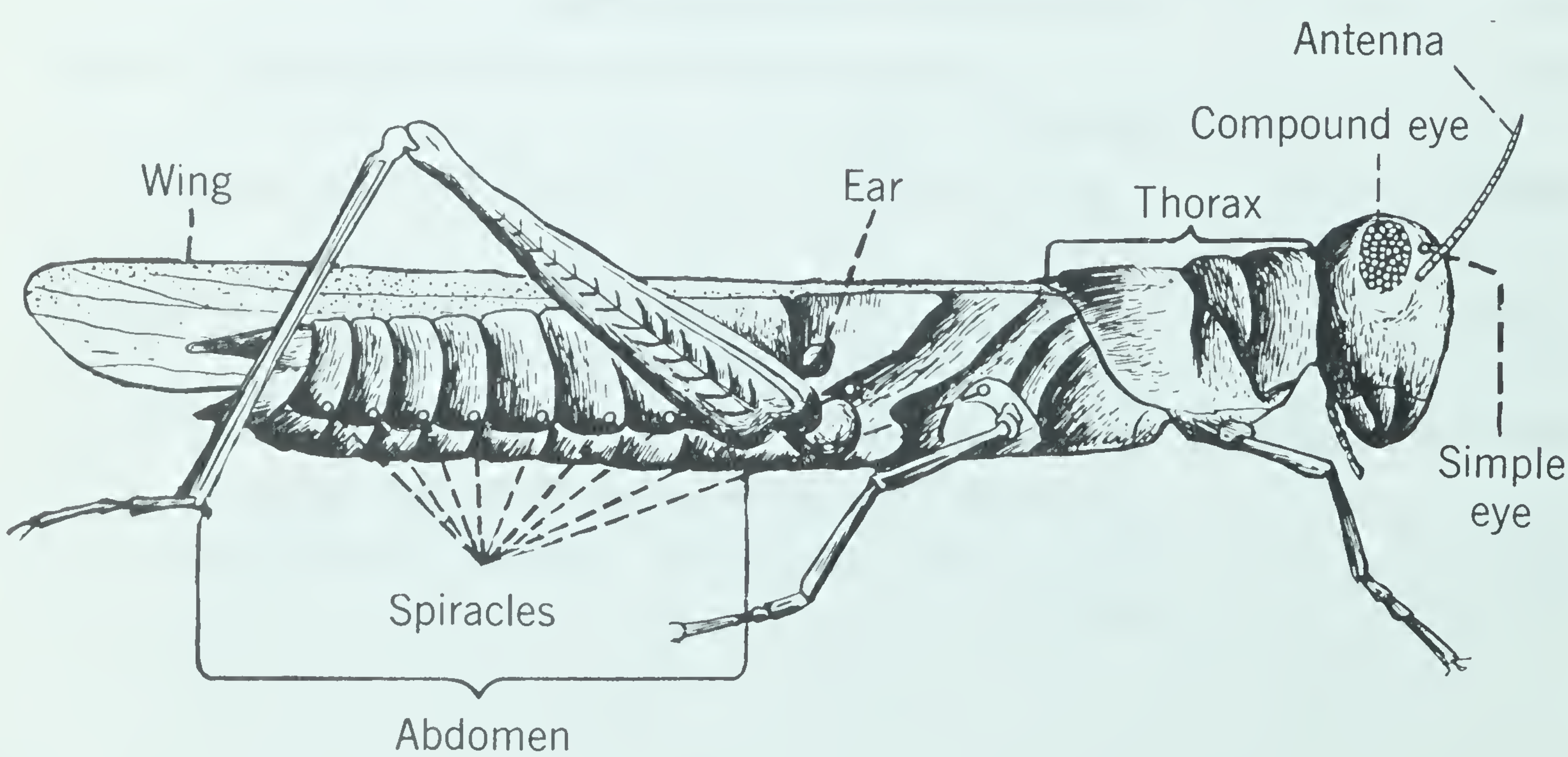


Fig. 18-1. The grasshopper is a good example of an insect to use for classroom study.

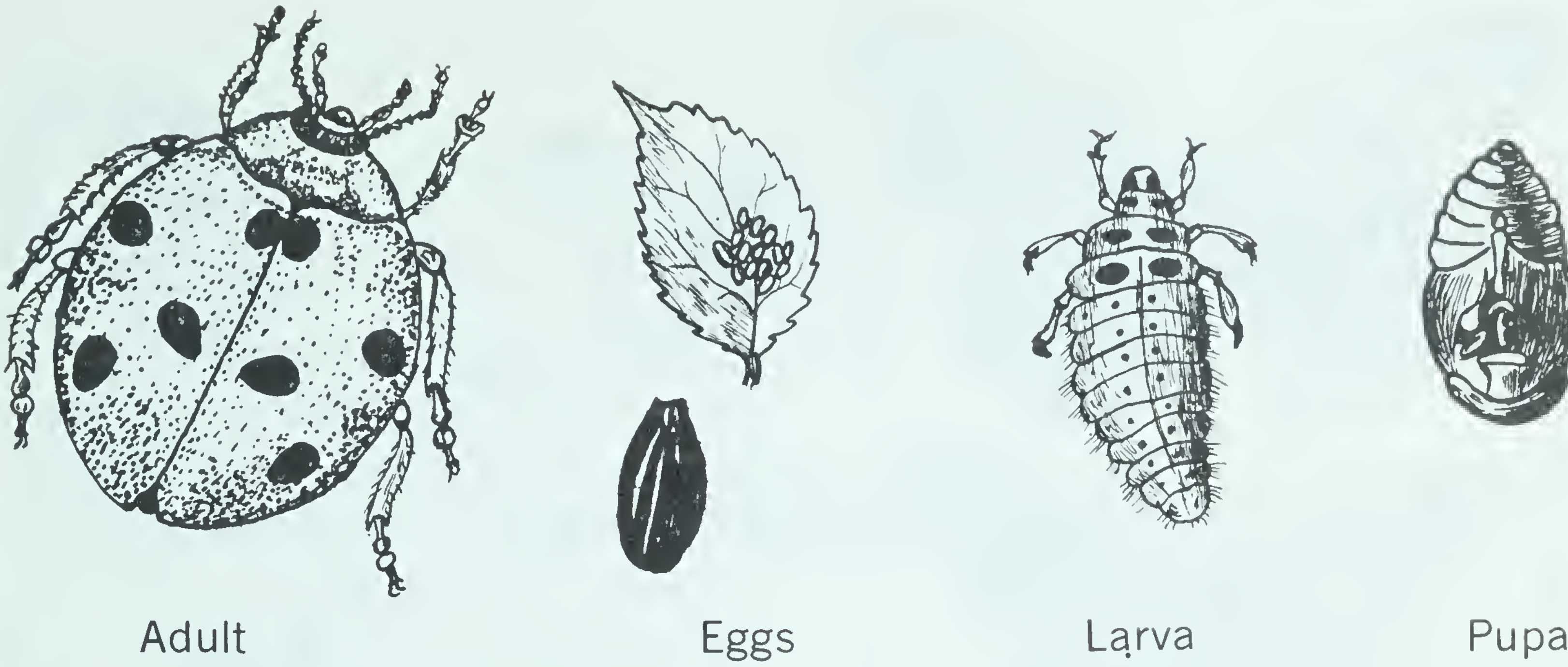


Fig. 18-2. The ladybird beetle passes through three distinct stages after hatching from the egg. It is therefore said to undergo complete metamorphosis.

complete metamorphosis. Other insects may develop by a gradual growing process with no marked changes in form. For example, the newly-hatched grasshopper, known as a nymph, resembles the adult and changes only slightly in general appearance until full-grown. We describe such gradual development as *incomplete metamorphosis*. Besides the grasshopper, the dragon fly, the praying mantis, certain locusts, and many other insects develop in this way.

A more detailed and more scientific method of classifying insects is on the basis of the kinds and numbers of wings. Thus scientists have been able to divide all the known insects into some fifteen groups, known as *orders*. Six of these orders, comprising our most common insects, are described in the brief summary below. You will observe that each order is given a scientific name, derived in each case from the Greek root *pteron*, meaning "wing."

1. Order *Orthoptera* (Straight wings). Four wings. The outer pair of wings meet in a straight line along the back; the inner pair are folded. Examples: grasshopper, cricket, cockroach.
2. Order *Lepidoptera* (Scaly wings). Four wings covered with scales. Examples: butterflies, moths.
3. Order *Coleoptera* (Sheath wings). Four wings. The outer pair is hard and the inner pair large and folded. Examples: beetles.
4. Order *Hemiptera* (Half wings). Four wings. The hinder part of the outer wings are thin and trans-

Fig. 18-3. The nymph of the grasshopper gradually develops into the adult form. It is therefore said to undergo incomplete metamorphosis.

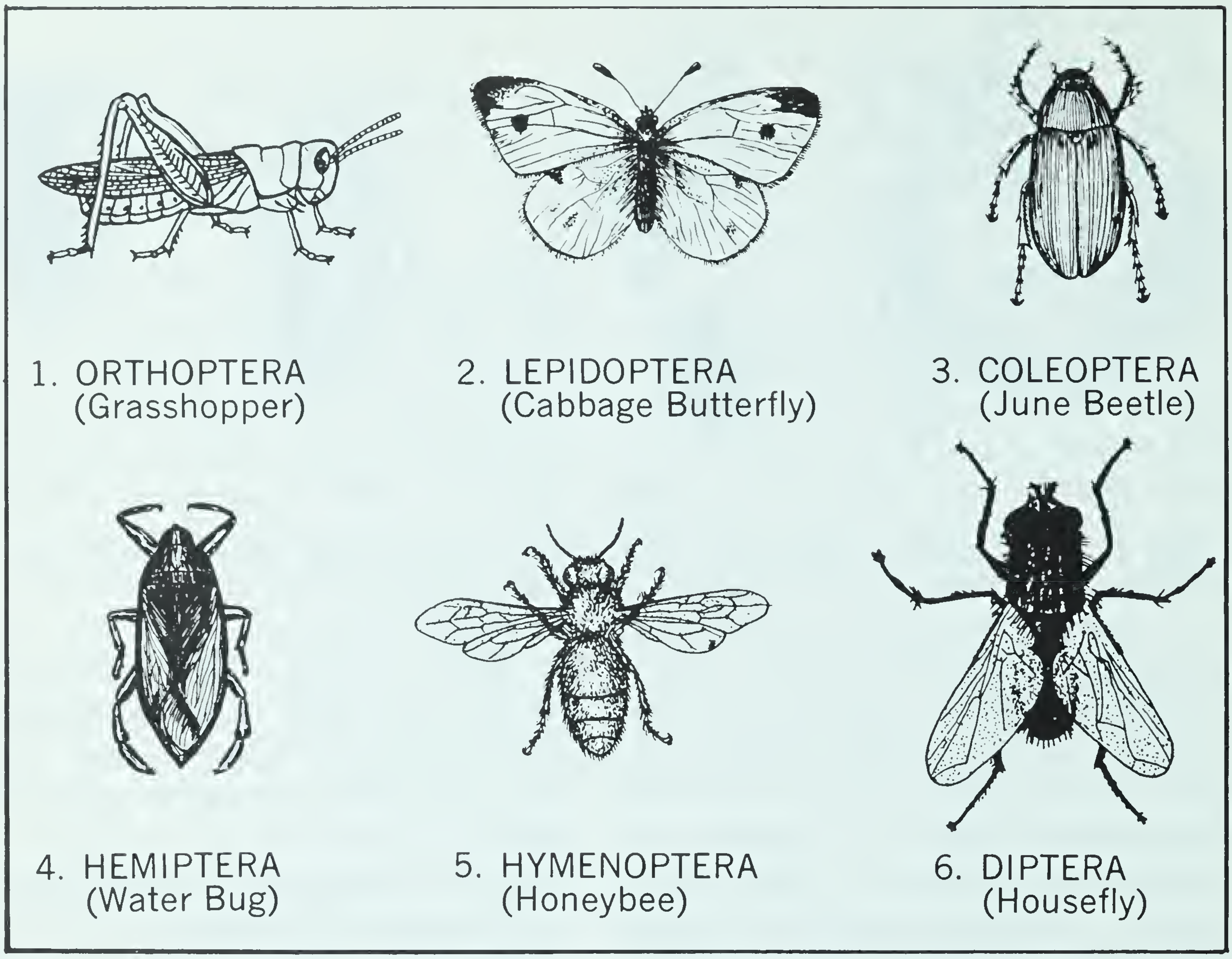


Fig. 18-4. What are the distinguishing characteristics of these six common orders of insects?

parent. Some members of this order have no wings. They all have piercing and sucking mouth parts. Examples: the bugs, Stinkbug, Squash Bugs, etc.

5. Order *Hymenoptera* (Membranous wings). Four similar, delicate membranous wings, of which the front pair is larger. Examples: bee, ant, wasp.
6. Order *Diptera* (Two wings). Examples: flies, mosquitoes.

REVIEW QUESTIONS

1. Name the main characteristics of a typical insect. **2.** State two reasons why a spider could not be classed as an insect. **3.** Name three insects with biting mouth parts and two insects with sucking mouth parts. **4.** Distinguish clearly between complete metamorphosis and incomplete metamorphosis. **5.** Why do scientists classify insects? State two good reasons for this. **6.** Scientists sub-divide the class Insecta into some fifteen orders. What is the main characteristic upon which this classification is based? **7.** Butterflies and moths belong to the same order but there are differences between them. List three ways in which they differ. **8.** The exoskeleton does not grow with the insect. How is this difficulty overcome?

B Why are insects so numerous?

Insects are the most numerous of all living things. There are roughly over 600,000 kinds of species of insects, and a great number of individuals of each kind. It is certain that there are many insects yet to be discovered, but the known ones comprise about 75 to 80 per cent of all the known living animals.

Insects are found almost everywhere. They inhabit the land surface, fresh-water ponds and streams. Some have learned to live in deserts, others in the cold regions of the earth, and some are found in the coastal or shallow waters of oceans. It has been estimated that there are about 25 million insects to the square mile. No wonder the work of controlling them is a never-ending task!

There are various reasons why insects exist in such large numbers. Certain characteristics aid them in the struggle for survival.

For one thing, the exoskeleton of the adult insect gives excellent protection. It is strong and firm; the insect is not easily crushed. Yet this tough covering is light enough to allow an insect to run or jump quickly to elude its enemies.

Many insects are very small. They can crawl into cracks and crevices, or hide under leaves, stones, and twigs to escape notice.

Some insects have jumping legs that enable them to take enormous leaps. Others have well-developed wings, using the power of flight to help them to avoid capture.

Fig. 18-5. The Monarch Butterfly, above, is unpalatable to many birds. By resembling the Monarch closely, the Viceroy Butterfly, below, is often able to escape destruction.

You have probably observed that the color of an insect often blends with the environment. This adaptation is known as *protective coloration*. For example, the caterpillars which feed on fresh green leaves are usually green; the adult grasshopper blends with the coloring of the fields and roadsides in late summer and fall.

Many edible insects resemble insects that are not edible and in that way secure immunity from attacks of their enemies. Birds tend to avoid the Monarch Butterfly but relish the Viceroy Butterfly. However, the latter often escapes destruction because it resembles the Monarch closely in color and in general appearance. This protective adaptation is known as *mimicry*. Wasps

are feared on account of their stings. Certain flies and moths are avoided because they are similar to wasps in appearance. These are further examples of mimicry.

Insects are able to use many kinds of food, hence there is little competition for food with other animals. Bees and butterflies suck the sweet nectar of flowers. The larvae of the clothes-moth feed on woollen materials and on fur. Sow Bugs eat decaying organic material. Termites and certain wood-boring insects gorge themselves on dry wood. Bedbugs and mosquitoes suck blood. Some insects, such as certain moths, may exist for long periods without any food at all.

Some injurious insects have no enemies. Also many pests of our field crops thrive because natural enemies are lacking in the areas where they are operating. Ladybird beetles were brought from far-away Australia to help destroy a species of scale insect that was causing great damage to lemon and orange trees in California. The Japanese beetle came to America in a shipment of small trees and shrubs from the Orient. The larvae of the Japanese beetle feed on the roots of grasses; the adults attack the leaves of fruit trees, grapes, corn, and garden crops. Widespread destruction has been caused by this imported beetle because it has apparently few, if any, natural enemies in its new environment.

The young of insects are usually protected. Some insects (certain aphids) are born alive, but most insects hatch from eggs. The eggs are small and not easily seen. The female adult usually deposits them in a safe place, such as on the under surface of leaves, in the crevices of bark, or in the soil, where they are sheltered from rain, wind and sun. In the pupal stage of a complete metamorphosis, the pupa cases are attached firmly to corners, or to forks of branches. Sometimes they are concealed in the surface litter of soil or even buried in the soil itself.

One of the most important reasons for the numerical superiority of insects is the fact that the female may lay hundreds of eggs in one season. In some species the young hatch and develop quickly, and may be ready themselves to lay eggs within a short period. For example, the female housefly deposits its elongated, pearly-white eggs in batches of 100 to 150 in manure, garbage, or other decomposing organic matter. It is possible for one female to lay 600 eggs or more during her lifetime. In warm weather, the larvae may reach the pupal stage within one week. The pupal stage lasts about a week, more or less, depending on the temperature. Thus, in favorable weather, the period from the time the egg is laid until the adult fly appears may be less than two weeks. You may easily understand from this that under favorable conditions the total number of descendants of one housefly may number into the millions by fall.

REVIEW QUESTIONS

1. Name five factors favoring the survival of insects. **2.** State what is meant by protective coloration and give an example. **3.** State what is meant by mimicry. Give an example. Try to find an

example different than the ones given in the text. **4.** Suggest a purpose for the bands of color on wasps.

C What insects are of economic importance?

Many insects are friends of man. They help us in many ways by making things that man can eat, wear, or use. Drop by drop, the *honeybee* gathers nectar from flowers and brings it to the hive. The nectar is made into honey that man may use for food. The *silkworm* spins a cocoon of silk threads. Man unwinds the threads and makes them into cloth. The *Tachina Fly* destroys other insects by laying eggs on the larvae. The eggs hatch and grow in the body of the host insect, resulting eventually in its death. The *Ladybird Beetle* feeds upon plant lice and other harmful insects that destroy trees and crops. The *Carrion Beetle* attacks and destroys the dead flesh of animals, thus rendering service as a scavenger; other beetles bury dead animals by tunnelling under them. The common *dragonfly* is another friend to man as it lives chiefly on mosquitoes and small flies.

There are other ways in which insects are useful. Some plants cannot produce seeds without help. The blossoms on pumpkin vines, for instance, are not all alike. One kind of blossom carries pollen; the other kind is ready to produce fruit. Before the fruit will grow the pollen from one kind of blossom must be carried to the other kind. In order to transfer the pollen the plant must depend upon either the wind or insects. When insects draw the nectar from a flower their bodies become covered with pollen. They spread this pollen from flower to flower thus helping plants produce strong, healthy fruit and seeds.

Shellac is made by the *lac insects* of India. These very tiny insects stick to twigs of trees, sucking the sap with their tiny beaks. The pores of their body give off a sticky juice which hardens at once into a shell to protect the insect from its enemies. From this hard shell man has learned how to make shellac. Shellac can be made into varnish and is used to give a tough, hard finish to woodwork and furniture.

Many insects are enemies of man. Some annoy people by biting and stinging them; others injure furniture and houses, damage clothing, trees and food crops. Most dangerous of all are the insects that carry the germs of dread diseases.

Lice, mites, fleas, and many kinds of *flies*, attack domestic animals by biting them and sucking their blood. Poultry, dogs, sheep, and other animals, when attacked by these pests lose weight and become sickly. For example, one of the troublesome flies, known as the *bot-fly* injures sheep and horses. This fly lays its eggs on the hairs of the victim's legs. The horse or sheep, by licking itself, takes the eggs into its mouth. The larvae develop in the stomach in large numbers and damage the stomach walls. The *Warble Fly* attacks cattle. The adult fly lays its eggs on lower parts of the animal's

Fig. 18-6. The housefly carries disease germs.

body. The larvae develop under the skin, and later bore through the skin of the back, thus causing severe damage to the hide.

In warm countries an insect known as a *termite* attacks dead wood. Logs, piled lumber, furniture, and the walls and timbers of houses may be destroyed.

The larvae of the *clothes-moths* eat wool and fur. They destroy clothing to the value of millions of dollars annually. *Carpet Beetles* injure rugs and carpets.

Various insects attack our forests. They bore into the trees, feed upon the leaves, thus reducing growth or destroying the trees completely.

Locusts have affected man since the beginning of time. Plagues of locusts are still common today in parts of Africa and elsewhere. The damage caused by the *grasshopper*, a form of locust, is widespread and so serious that we shall discuss it in detail in a later section. Indeed, insects do the chief damage to our crops. There are so many kinds of such insects, with varied food habits, that they are able to attack plants in all stages of growth. *Wireworms* may attack the seed as soon as it is sown, boring into the germ. Later, they eat into the central portions of the young seedlings. *Cutworms* chew at the stem as the plant comes through the ground. *Plant lice, Chinch Bugs, Armyworms, Hessian Flies*, are prepared to suck the vital plant juices, or otherwise to destroy the leaves and stems. Even stored food is not immune to damage by injurious insects. Certain worms and weevils attack flour and stored grains. Numerous insects attack fruit trees. For instance, the larvae of the *Codling Moth* cause serious damage in all the apple and pear-growing districts of Canada. *Leaf rollers, scale insects, tent caterpillars, canker worms*, and others, damage ornamental shrubs, shelter-belts and shade trees.

Of all our insect enemies, those that carry disease are the most dangerous. Fortunately, comparatively few of the many thousands of insects are disease carriers.

The *housefly* and *cockroach* may bring to us the germs of typhoid, tuberculosis, and other such diseases. *Body lice*, which thrive wherever proper cleanliness is not maintained, may carry trench fever or typhoid.

If there were no mosquitoes, there would be no malaria. *Malaria* is a very dangerous disease, especially in damp, tropical regions. It is caused by a germ which must live part of its life in the body of a certain kind of mosquito. When a mosquito carrying malaria germs stings a person, it leaves in the wound some of the germs of malaria which may cause the disease to develop. The germs of *yellow fever* are

also carried by a certain type of mosquito.

Bubonic plague is a disease of rats. Man cannot catch the disease directly from these animals. But, if a flea bites a rat suffering from plague, it takes the germs into its system. If the flea later bites a human being, the germs may find entrance into the victim's body. Likewise, *spotted fever* is contracted through the bite of a tick which is a parasite on many animals. No doubt you have read about the *Tsetse* (*set*-see) *Fly*. This fly, which is common in parts of Africa, carries sleeping sickness in much the same way that mosquitoes carry malaria.

We have mentioned just a few of the insects that carry disease. But it is not difficult to understand that this is one way in which an insect can be a very real menace to man.

Insects that are either useful or harmful to man are known as economic insects. If we say that an insect has no economic importance, we mean that it does not harm man, directly or indirectly, nor does it help him in any way.

Later in this Unit we shall study in detail some of the insects that injure our gardens and field crops. These insects are of great economic importance to the farmer and to all of us who depend upon agriculture for the production of food.

PUPIL ACTIVITY

Gather the pupae or cocoons of various insects in order to study the life cycles. Better still, get the larvae and keep them through the pupal stage till the adult emerges. In this way you can be sure you know the type of larva from which any adult comes.

When a caterpillar or other larva is taken, note (if possible) on what it is feeding, so that it may be supplied with the same kind of food in captivity.

Larvae should be kept in a shallow wooden box. Soil should be provided at one end of the box since some larvae go into the soil for the pupal stage. Do not forget to provide holes for ventilation.

Another interesting activity would be to gather grasshopper egg pods along with a quantity of soil. Discover if it is possible to get the eggs to hatch. If they do, you may study the growth of the young nymphs. Do not neglect to feed them. Grass seed sown in the soil of a shallow box with a glass top soon provides excellent "pasture" for the young nymphs. Watch the nymphs dispose of their exoskeletons as they grow. At what stage do the wings appear?

REVIEW QUESTIONS

1. What do we mean by insects of economic importance? **2.** Name five insects of great economic importance in western Canada. **3.** Describe two ways in which bees are helpful to man. **4.** Explain how bot-flies and the Warble Fly injure livestock. **5.** Why should we avoid destroying Ladybird Beetles in our garden? **6.** Explain how disease may be spread by mosquitoes.

D How are destructive insects controlled?

Nature helps to keep insects under control. *Weather conditions,* such as

extremes of heat or cold, rainfall and winds destroy young larvae. The available food supply also influences the growth and numbers of insects.

Birds eat insects and insect larvae. Also, they carry large numbers of larvae to feed hungry offspring. It is estimated that birds may save farmers and gardeners about 25 per cent of the damage to their crops.

Besides the birds there are other *natural enemies* of insects, such as frogs, toads, skunks, snakes, and Ladybird Beetles.

Some insects act as *parasites* on other insects. Chief among these are the parasitic flies. The Ichneuman (ick-*new*-mon) Fly larvae eat egg masses or act as parasites on caterpillars. The Tachina Fly (mentioned in a previous section) is also a well-known insect parasite.

Man, too, has learned how to control harmful insects. To apply proper control measures he must study (1) the feeding habits of the insect; (2) the life history of the insect.

The principal method of control is the use of poisons, known as *insecticides.* A good insecticide must be effective, cheap and harmless to the host (the plant on which the insect feeds). Insects with *biting mouth parts* are controlled by means of *stomach poisons*, such as Paris Green or Arsenate of Lead. Insects with *sucking mouth parts* are controlled by means of *contact poisons.* These poisons plug up the breathing pores and the insect suffocates. The feeding tube of sucking insects penetrates beneath the surface tissues of the host, hence stomach poisons would not be effective. Nicotine Sulphate is a commonly used contact poison. Soap, kerosene, fish oil, and sulphur, are also used. Some poisons are both contact and stomach poisons. Derris, pyrethrum, aldrin,

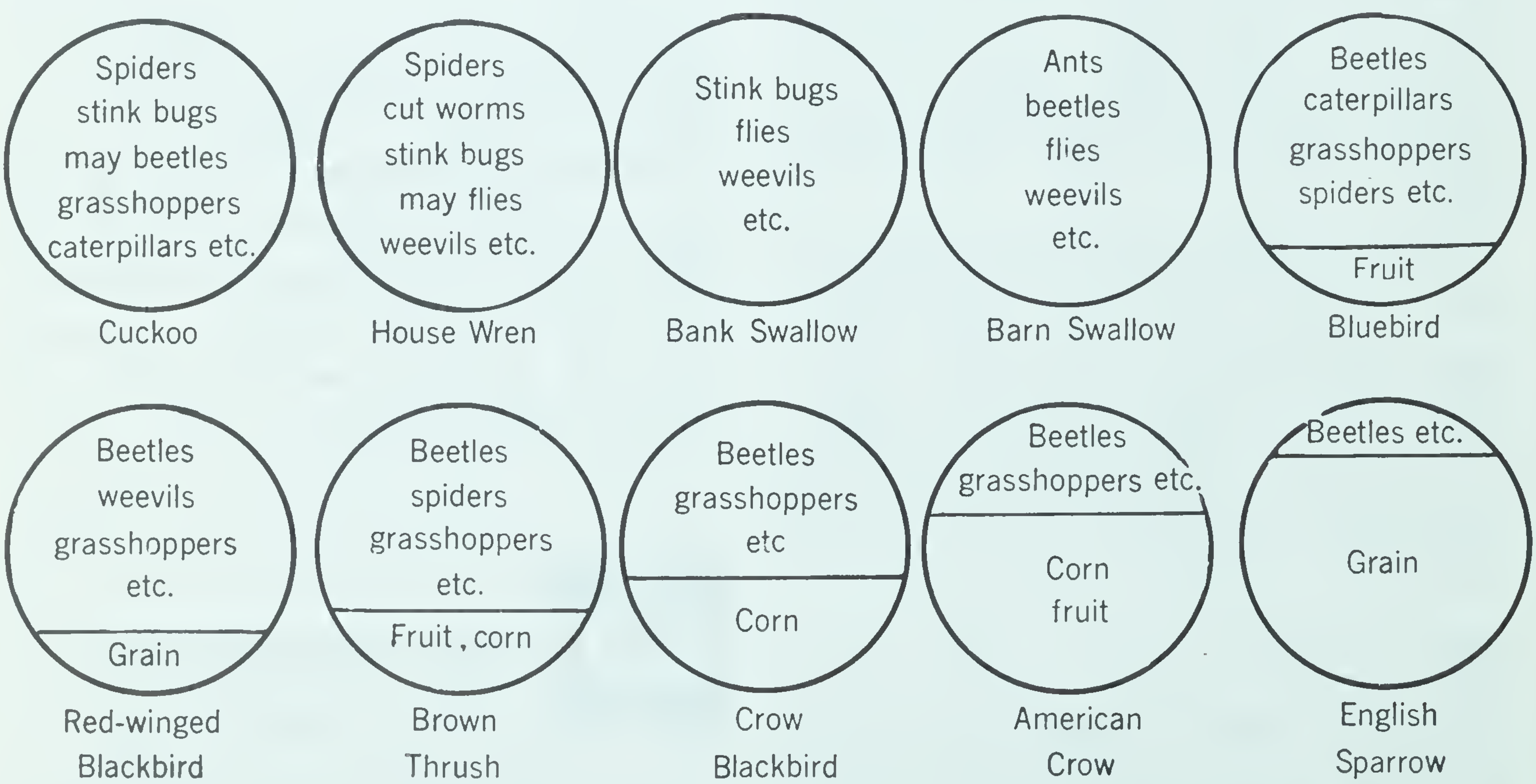


Fig. 18-7. This chart shows you certain food items in the diets of some common birds. Note that insects are an important source of food.

chlordane, and D.D.T. have this two-fold effect.

Sometimes man uses *cultural* and other methods to destroy injurious insects. Thus, shallow fall cultivation of the soil breaks up the egg pods deposited by the female grasshopper. Further cultivation in the spring aids in starving the young hoppers. Burning infested stubble helps to destroy sawfly larvae. By using his knowledge of when an insect may be expected to begin feeding, the farmer may plant his crop early, or he may delay planting to gain a measure of starvation control. For instance, corn planted late in the spring is less liable to attack by the corn-borer.

When a destructive insect feeds on only one kind of crop, it is helpful to *rotate crops*. For example, if sawflies are a problem, it might be advisable to switch from wheat to flax or oats, which are immune. Oats and barley are more resistant to wireworms than wheat, and so on.

Another effective method of control is by means of *traps*. When the farmer is tilling his summerfallow, he may leave weedy strips at intervals. The grasshoppers gather in these strips to feed, and great numbers may be destroyed there with poison. The use of traps will be described in more detail in a later section.

REVIEW QUESTIONS

1. Describe four ways by means of which nature helps to control insects. **2.** What is an insecticide? **3.** Name two insects with biting mouth parts and state what type of poison should be used to destroy them. **4.** Name two insects with sucking mouth parts and state what type of poison should be used to destroy them. **5.** Aphids have sucking mouth parts. Why is a stomach poison not effective in destroying aphids? **6.** State three reasons why we should conserve and protect birds. **7.** What do we mean when we speak of cultural methods of destroying insects? **8.** How would a rotation of crops help to control insects? **9.** Explain briefly what is meant by insect traps.

Fig. 18-8. The illustration at the left shows a tiny wasp laying its egg in the egg of another insect. At right another wasp is shown parasitizing an aphid.

E What insects injure our gardens and how do we deal with them?

Numerous insects attack our gardens. It will not be possible to describe all of these insects. Some of them do harm to vegetable crops; others attack flower gardens, orchards, shelter-belts, and shade trees. In this section we shall describe briefly the injurious insects that are common in the gardens of the prairie provinces.

Cutworms attack many garden crops. Whenever you see stems cut off at the ground level, you should immediately suspect cutworms. If you dig down into the soil, probably you will find the fleshy caterpillar curled

Fig. 18-9. The larva of the Cabbage Butterfly feeds on green leaves.

up near the roots of the plant. Some cutworms feed by night and hide in the soil during the day. They are most active during May and June.

Control consists of scattering poison bait on a warm evening, or spraying the soil surface with *aldrin* or *chlordane* solutions. It is best to apply the poison to the soil before the plants appear, as care must be taken to avoid spraying the edible portions.

If the cutworms are not too numerous, and only few plants are affected, an interesting control measure is to use cans or paper collars. These may be sunk three inches in the soil, thus protecting the upper parts of the roots and the base of the stem. Young cabbage and cucumber plants are often saved in this way.

Cabbages, cauliflowers and turnips may be injured by larvae of the cabbage butterfly. The adult butterfly is yellowish-white with black markings on the tips of the wings. Eggs are laid upon cabbages or similar plants where they hatch in a few days.

The larvae feed on the leaves and hearts of the plants. The damage may continue throughout the summer.

Various poisons may be used to control cabbage worms. D.D.T. may be used on young plants. But, as soon as the heads (cabbages and cauliflowers) begin to form, we must be careful to use only *derris* or *pyrethrum*, as these dusts are non-poisonous to humans.

The Potato Beetle is another well-known pest. The insects we often refer to as potato bugs are not, in reality, bugs at all, but beetles, that pass the winter in the ground. In the early spring the adult beetles emerge, and the females lay orange-colored eggs on the leaves of young potato plants. The eggs hatch in about ten days. The larvae are fully developed in two weeks, when they enter the ground to pass the pupal stage. There are several generations in one season.

Both the fat, reddish larvae and the yellow-backed adult beetles feed on the foliage of the potato plants during the whole summer. As the green leaves are the *lungs* and *factories* of the plant, the damage done by the beetles may destroy the plant entirely, or at any rate greatly decrease the yield.

The leaves should be dusted with derris or D.D.T. solution as soon as the larvae or beetles appear. If more drastic measures are called for, concentrated sprays of *D.D.T., aldrin* or *chlordane* may be used. These sprays should be mixed and applied according

to the directions set out on the containers.

Tiny, round holes eaten in the leaves of cabbage, turnip, or radish plants may be caused by Flea Beetles. These insects are very small and are quick jumping beetles. If unchecked, they will destroy rows of young plants in a very short time. Flea Beetles are present in the spring until July, and may appear in August and continue their activities into the late fall.

Early control measures are important. Plants should be dusted with derris, or sprayed with a D.D.T. solution just as soon as they emerge from the ground or are transplanted. Repeat as necessary. Of course, we must remember to use derris on cabbage heads, and on radishes and turnips, when the roots begin to protrude above ground.

Aphids (plant lice) may be present in gardens in large numbers. Aphids injure foliage by sucking juices from plant tissues. Currants, peas, fruit trees, sweet peas and many other kinds of plants, may be damaged by aphids. The leaves become deformed, curled, and finally may lose color and drop to the ground. The aphids may be found clustered on the underside of the leaves, or seeking shelter in heavy foliage, or in the damp grass of nearby lawns.

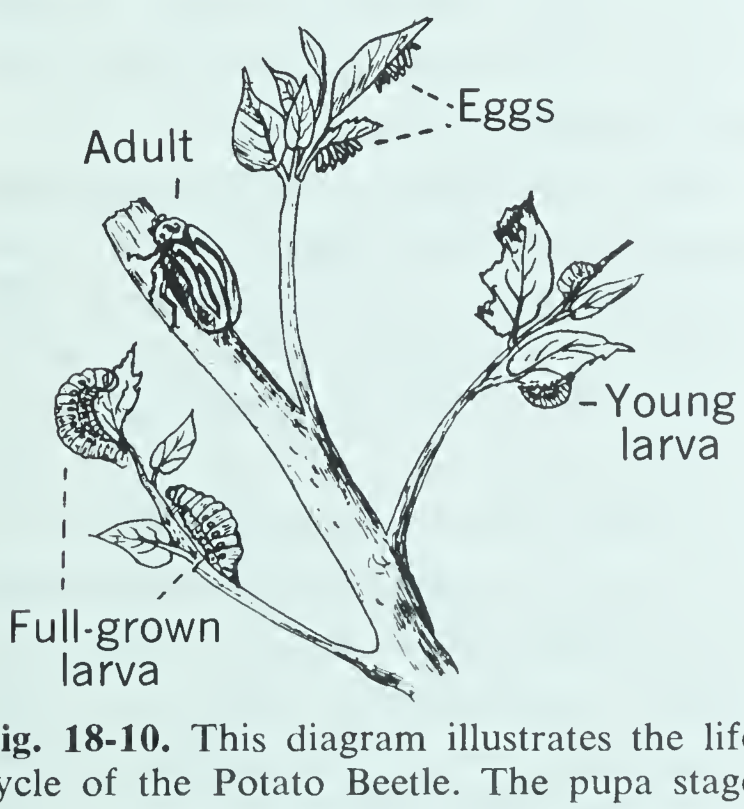


Fig. 18-10. This diagram illustrates the life cycle of the Potato Beetle. The pupa stage is not shown, since the larva drops to the ground and pupates in the soil.


Fig. 18-11. Aphids suck the juices from the leaves and stems of roses and other plants.

As aphids have sucking mouth parts, we must use a *contact poison* to destroy them. The insects and leaves should be sprayed with *nicotine sulphate* solution. The spray should be directed especially against the undersides of leaves. Repeat as necessary.

REVIEW QUESTIONS

1. Name five insect pests of prairie gardens. **2.** How would you recognize cutworm damage? **3.** Why do we use derris or pyrethrum on our food crops? **4.** To

what order of insects does the adult of the cutworm belong? **5.** State two precautions to be taken when using D.D.T. **6.** Explain how the Potato Beetle helps to reduce the yield of potatoes. **7.** How do aphids injure garden plants? What plants do they attack? **8.** You observe that a row of young radish plants have numerous tiny holes in the leaves. What insect would you suspect caused this damage? Describe the insect briefly. **9.** To what order of insects does the Cabbage Butterfly belong? Describe briefly the life cycle of this insect.

F What insects destroy our field crops?

The value of the grain crops destroyed annually in western Canada by insect pests runs into many millions of dollars. A great deal of this loss may be prevented by scientific control measures. But, before attempting control, the farmer must know what insect is involved, and also understand its life history and feeding habits.

The Wheat Stem Sawfly attacks our wheat crops. You may see the adult sawfly in the wheat fields any time from June to about mid-July. It is a wasp-like fly with dark-colored, narrow yellow bands on the abdomen. The females lay eggs, beginning about mid-June, on the stems of grains and grasses just above the top joint. The eggs hatch in from three to four days. The grubs (larvae) begin to work down through the stem, eating through the inner parts as they descend. About August 1 they reach ground level where they girdle the stem, thus weakening it. Usually the stem breaks off. The larvae then seal the stubs of the stems with *sawdust* and remain within the stubs over winter. In the spring the larvae change to pupae, later emerging as adults.

Spring rye and certain varieties of barley, as well as wheat, may be attacked by the Wheat Stem Sawfly.

The chief loss caused by this injurious insect is a decrease in yield due to fallen stems, or failure of the grain to fill and mature properly.

What can the farmer do to prevent or lessen the damage caused by sawfly? For one thing, he may grow either *Chinook* or *Rescue* wheat. Both these varieties are immune to injury. Flax and oats are also immune.

A method that is sometimes used to protect a main crop is to sow a *trap crop* of Brome grass or early wheat (about one rod in width) around the main field. The adults lay their eggs in the traps. The trap strips are harvested earlier than the main crop, thus few sawflies survive.

The wireworm is another injurious pest of our field crops. The life cycle of this insect is quite interesting. The adult is a shiny black beetle, known as a *Click Beetle*. In the spring the female beetles burrow into the soil, where they lay tiny white eggs (May-June). In a few days the eggs hatch. The larvae are very hard-bodied, slender (hence are called "wireworms"), yellow in color, measuring about three-quarters of an inch long when full-grown. These larvae may live on an average of five years

in the soil after which they change into the pupal stage. Adult Click Beetles emerge and remain underground until the following spring.

Wireworms cause damage to many field crops, especially to wheat, corn, sugar beets, and potatoes. The first sign of injury in grain fields is a noticeable patchy condition or thinning-out of the young crop. The injury is caused by the larvae which attack the seed as soon as it is sown. Later the growing centers of the young stems are entered and destroyed.

The best method of controlling wireworms is to use chemical seed treatments. The most widely used chemicals for this purpose are *aldrin, dieldrin,* or *lindane*. The seed is treated with these seed dressings before it is sown. This will give immediate control of wireworms for wheat, oats, barley, rye and flax. It is recommended that wheat should be treated at a rate that will apply one ounce of the insecticide per acre. The directions for mixing are printed on the containers and should be followed carefully.

Good cultural methods also aid in wireworm control. Anything that will speed up the growth of the crop is effective. For instance, the following practices will aid in reducing damage:

(1) Seed into a firm, clean, seedbed.

(2) Seed into moist soil; seed not deeper than three inches.

(3) Use fertilizers on the soil in areas where they usually increase the yields of grain.

Of course, the ideal combination is to use seed dressings along with the good farming practices listed above.

Fig. 18-12. The Click Beetle is the adult form of the wireworm.

In some years grasshoppers cause great injury to prairie crops. Usually scientists are able to forecast in advance when a serious plague of grasshoppers is to be expected. They do this by conducting an "egg count" over a wide area of the prairie region in the fall. From the information gained in this manner, maps are drawn to show in what areas grasshoppers will be most plentiful in the following spring. The first forecast is published in the press in the fall in order to help the farmer decide about fall tillage. In midwinter another forecast appears in the press and colored maps are placed in post offices and other public buildings. The farmers should watch for these forecasts.

There are over 75 kinds of grasshoppers found in western Canada. Of these, just three or four species are injurious to field crops.

Fig. 18-13. This photograph shows the female grasshopper laying eggs.

The female adult lays eggs in the soil. The eggs may be laid near cultivated fields, in pastures, on the roadside or scattered throughout the stubble fields. If the eggs are present in any quantity in stubble land, it is best to summerfallow that land and not attempt to grow a crop on it. It can be cropped only at great risk and at considerable expense in time and money needed for control measures. In fact, it is a good idea to do shallow tillage in the fall, thus breaking up the egg pods and exposing the eggs to frost, alternate thawing and freezing, and so on. Tillage of the stubble land again in the early spring is very effective as it helps to attain starvation control. That is, if all weeds and other growth are destroyed the newly-hatched nymphs (you will recall that grasshoppers undergo incomplete metamorphosis, with no larval stage) may actually starve to death.

Sometimes, due to adverse weather conditions or for other reasons, it is impossible to till the stubble land early in the spring. Hence, before the farmer can begin tillage, the grasshoppers may be partially grown. Then the farmer's main aim must be to protect uninfested crops, particularly his crop on the field that was summerfallowed the year before and which would itself be free of grasshopper eggs. In such circumstances, when starting to till, the farmer should plough a strip at least two rods wide around the outside. Then he may miss the next two or three rods, leaving a weedy *trap strip*. He continues tilling, leaving traps in this manner, according to his own judgment. Poison may be applied to the trap strips as the young grasshoppers tend to gather there in order to feed.

We have mentioned poisoning the grasshopper nymphs. The use of modern sprayers and dusters along with the latest insecticides is, of course, the best method of control, as it is convenient, effective and not too expensive. But *poisoning must be done early.* Hatching may begin as early as the first week in May, but usually is at its peak during the period May 20-June 10. A newly-hatched grasshopper is only about one-eighth of an inch long so care must be taken to examine fields carefully and frequently for the first signs of activity.

Aldrin, chlordane, and *dieldrin* are very effective for use in sprays, dusts, and baits. These poisons are both stomach and contact poisons so should be applied both to the grasshoppers and their food plants. Baits made up by mixing poison with sawdust, bran, etc., are more commonly used on a small

scale, in gardens for example.

Two kinds of cutworms are serious pests in western Canada in the spring. Since the control methods are different with each, it is important to distinguish between them. The *Pale Western Cutworm* is a uniform pale gray color, and mainly damages crops in the open prairie region and in the margins of the park-belts. The *Red-backed Cutworm* is medium dark gray on the upper half of the body and has two dull-red stripes along the back. It normally occurs in the park and forest areas but sometimes extends into the open prairie.

Pale Western Cutworm moths lay their eggs from mid-August to mid-September in loose soil. The eggs hatch in the spring and the larvae begin to attack the crop by cutting completely through the young stems at, or just below, the soil surface. If many cutworms are present, the fields thin out rapidly. All field crops (and garden crops) are susceptible to damage.

Reseeding of ruined fields is not safe until the cutworms have ceased to feed, that is usually between June 20 and June 30. Of course this is too late for wheat, so the farmer must choose some other grain, such as barley.

Poison baits are not effective against the Pale Western Cutworm, as the larvae remain below the surface. Sprays of some of the newer insecticides (chlordane or dieldrin) may be helpful, if applied to the crop when the damage first appears. However, something can be done to prevent another, and perhaps more severe, infestation the following year. As mentioned above, the adult moths prefer to lay their eggs in soft, dusty soil. Hence, the farmer should use care in working his fallow. During the spring and early summer he should go over the fallow in the normal way, as recommended for weed control. As late in July as possible all weed growth should be destroyed. The fields should be left *undisturbed* by tillage or livestock until September 15. This is to insure that any crust formed on the soil surface by August rains will remain unbroken. If a good *crust* forms, the moths will be discouraged from laying their eggs. Sometimes, of course, fields left untouched in this manner will become quite weedy. Then the farmer must choose between the probable loss caused by weeds (in reducing moisture reserve) and that caused by a Pale Western Cutworm infestation the following spring.

Fig. 18-14. The Pale Western Cutworm is the most destructive cutworm in western Canada.

The adult of the Red-Backed Cutworm is a grayish-brown night-flying moth, slightly different in appearance from the adult of the Pale Western Cutworm. The eggs are laid early in the fall and hatch the following April.

The chief difference between the two kinds of cutworms is in the feeding habits of the larvae. Whereas the

Fig. 18-15. The Red-backed Cutworm feeds on the surface of the soil at night.

Pale Western Cutworm larva damages plants from *below the surface*, the Red-Backed Cutworm larva feeds *on the surface* of the soil at night. Hence *poison bait* may be used effectively against this pest in fields of sweet clover, flax, sunflower, corn, and in gardens and grain crops.

The bait may be prepared as follows:

25 lbs. bran
⅖ pint chlordane or aldrin
2½ gals. water.

Spread the bait thinly, on warm, calm nights, placing it along the rows.

If the first crop is destroyed, reseeding is safe within two weeks, if cutworms are one inch long, or within one week, if one and three-eighths inches long. Some bait may be used to aid in protecting the new crop.

All weeds on summerfallow land should be destroyed before August 1 and there should be no cultivation during the egg-laying period in order to encourage the soil to become crusted.

Certain insects even attack stored grain. Chief among these are the *Rusty Grain Beetle*, several kinds of *fungus beetles* and *mites.*

The larvae of the Rusty Grain Beetle feed on the germs of kernels of wheat, oats, and barley. The fungus beetles feed chiefly on molds in damp grain. Tiny mites feed on the grain dust as well as on the kernels.

Insect infestations in stored grain are usually caused by poor storage conditions. These may include storing the grain when it is tough or damp storing in badly constructed or leaky granaries that allow moisture to enter, or storing it in granaries where there is poor ventilation so that moisture condenses on the surface of the grain.

Damp grain begins to heat and to mold. Insects, if present, will multiply rapidly.

Grain that is kept dry will not usually become infested. Therefore, the farmer should be sure that it is stored in a dry condition in a weather-proofed, but well-ventilated granary. Before storage, the granary should be examined carefully and repaired where necessary. After storage, the grain should be inspected about every two weeks for signs of dampness or heating. Tests may be made by thrusting a metal rod or pipe of small diameter into the grain at various points. If the rod is left for at least ten minutes, it will become warm if the grain is heating. Off-condition spots should be examined for insects.

If insects are discovered, they may be controlled by cooling the grain to at least 25°F. for about ten days. This may be done by first cleaning the grain (fanning mill, etc.) and then transferring it in thin layers in cold weather to piles outside or to a dry bin or granary.

Another method of control is by

fumigation. Stored grain may be fumigated at any time of the year. As the chemicals used are extremely poisonous to man as well as to insects, they must be handled very carefully. Details for this type of control should be obtained from a federal government insect laboratory.

PUPIL ACTIVITY

Collecting and mounting insects is an interesting and educational activity. You will need a net to capture some of them. The net may be made by bending a wire to form a circle about 12 inches in diameter. Fasten the hoop to an old broom handle or pole of suitable length. To the wire attach a deep bag of mosquito netting.

When butterflies and moths are captured, you should grasp the wings gently and pour a few drops of gasoline on the abdomen (why the abdomen?) to kill the insect. With your fingers spread the wings fully and place a strip of paper across each wing. Pin the paper strips to cardboard as a temporary mounting.

Insects other than moths and butterflies should be placed in a killing bottle. For a killing bottle use a wide-mouthed jar. Put a ball of absorbent cotton, soaked in gasoline or chloroform in the bottom of the jar. Over it place a thin strip of paper to prevent the insects from becoming wet. Fill the jar loosely with strips of paper to keep specimens from packing.

Use a cardboard box or a cigar box as a container for permanent mounting. Place a sheet of cork or linoleum in the bottom. Make small paper labels, recording the name of the insect, the date and place collected. Stick pins through the thorax of the insect and pin securely to the bottom of the box. The labels should be placed on the pin below the insect.

It is advisable to mount insects with large wings (such as butterflies) in a separate box.

REVIEW QUESTIONS

1. Describe the adult sawfly. To what order does it belong? **2.** Where do wheat stem sawfly larvae spend the winter? **3.** Name two varieties of wheat that are resistant to wheat stem sawfly. **4.** What is the adult wireworm called? To what order of insects does it belong? **5.** Name one unusual thing about the life cycle of the wireworm. **6.** What is the first sign of wireworm damage in a crop? **7.** What are chemical seed dressings? Name three kinds that may be used to control wireworms. **9.** What is the purpose of shallow fall tillage in controlling grasshoppers? **10.** Describe the two types of cutworms that do damage in western Canada. **11.** How is the Pale Western Cutworm controlled? **12.** Why must grain in storage be kept dry?

G How are bees of value to man?

Of all the insects, bees are perhaps the most useful to man. For one thing, bees require an abundance of *pollen* to feed their young brood. As they

Fig. 18-16. The worker bee (left), the queen (middle), and the drone (right) each play an important role in the life of a hive.

gather pollen, and pack it into tiny baskets on the rear legs, many of the pollen grains cling to the bee's hairy body. Thus, the pollen is spread from flower to flower, making it possible for plants to produce seeds and fruit. Bees also gather nectar from flowers, transport it to the hive, where it is made into *honey*. When a surplus of honey is produced, man may collect it and use it for food. *Beeswax* is another important substance produced by bees. The wax is secreted from pockets on the insect's abdomen.

Bees are social insects and live in organized colonies. Each colony has a *queen*, several hundred drones, and thousands of *workers*. The queen is much larger than the workers. Her main function is to lay eggs. The workers are undeveloped females. Ordinarily they cannot lay eggs, but, when young, perform various tasks within the hive. Later, the workers become field bees, gathering nectar and pollen. The drones are the males. They idle away their days either in the hive, or in the nearby vicinity.

Bees undergo a complete metamorphosis. Early in the spring the queen begins to lay eggs in specially constructed six-sided wax cells. One size of cell (five to the inch) is known as a worker cell, and another size of cell (four to the inch) is known as a drone cell. The queen may lay either fertilized or unfertilized eggs. Normally, the fertilized eggs are placed in the worker cells, although sometimes they are deposited in a special queen cell, when the colony wishes to develop a new queen.

The thousands of eggs placed in the worker cells hatch into larvae. These are fed and cared for by nurse bees. Since a colony needs only one queen, these larvae are not permitted to develop into normal female bees. The small cell and meagre diet transforms them into worker bees (undeveloped females). It requires twenty-one days from the time the egg is laid until the

worker emerges an adult. There are four separate stages in this development. Three days are spent as an egg, six days as a larva, and twelve days as a pupa, before the adult emerges.

The queen lays unfertilized eggs in the drone cells. The eggs hatch after three days, but six and a half days are required for larval development and fourteen and a half days for the pupal stage.

When the queen begins to fail, or the colony decides to divide for various reasons, a new queen is required. The colony starts constructing over-size cells. The old queen deposits eggs in these cells. When the eggs hatch, the larvae are fed a special, rich food, called *royal jelly*. This food causes the larvae to develop into queens. The first young queen to emerge in the adult form usually destroys the other new queens by stinging them. Four or five days later the young queen leaves the hive. After mating with a drone she returns to begin her life-long work of egg-laying.

Man has learned to control bees and to make them work for him. Some people keep a few colonies of bees as a hobby or sideline, while others are commercial bee-keepers who derive all or most of their living from the sale of honey.

A study of the plants growing in a district will reveal its value as bee-keeping area. If there is an abundance of wild flowers, flowering shrubs and bushes, and dandelions, there will be a supply of nectar for the bees in the spring. Some of the common sources of nectar on the prairies are: crocus,

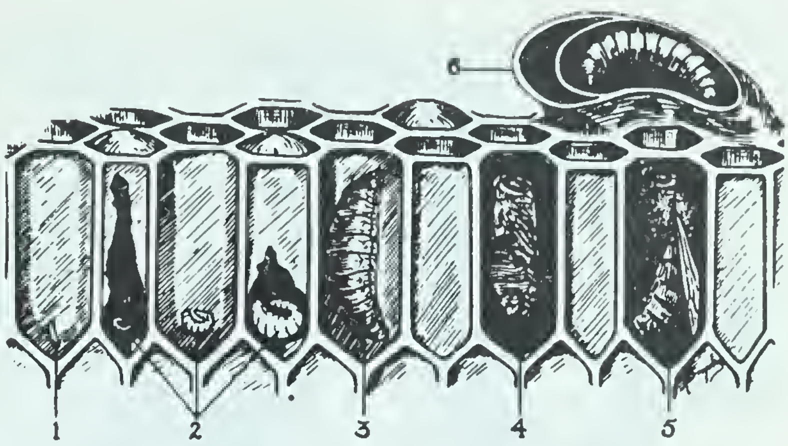


Fig. 18-17. This section of a comb shows the various stages of development of the Honeybee: (1) egg, (2) three stages of larvae, (3) fully developed larva, (4) pupa, (5) adult ready to emerge, (6) queen larva in queen cell.

willow, poplar, caragana, wolf willow, mustard, rose, clovers, fruit blooms, and dandelions. Sweet clover, alfalfa, and fireweed are the main sources for the honey crops of July and early August.

The equipment for a hive may be purchased from any supply house. The most common type of hive in western Canada is known as the *Langstroth.* Each hive of this type has a lower section or brood chamber in which the young bees are raised, and an upper section consisting of wooden frames or supers, in which honey is stored. More supers may be added as the honey store increases. The queen is kept out of the supers by means of a screen through which only workers may pass. This precaution is necessary to prevent the queen from depositing eggs in the honey cells.

A collection of hives is called an apiary. The *apiary* (*ay*-pi-airy) should be located in a grove of trees that will shelter it from the cold and winds. A good supply of nectar plants should be available within a radius of two miles.

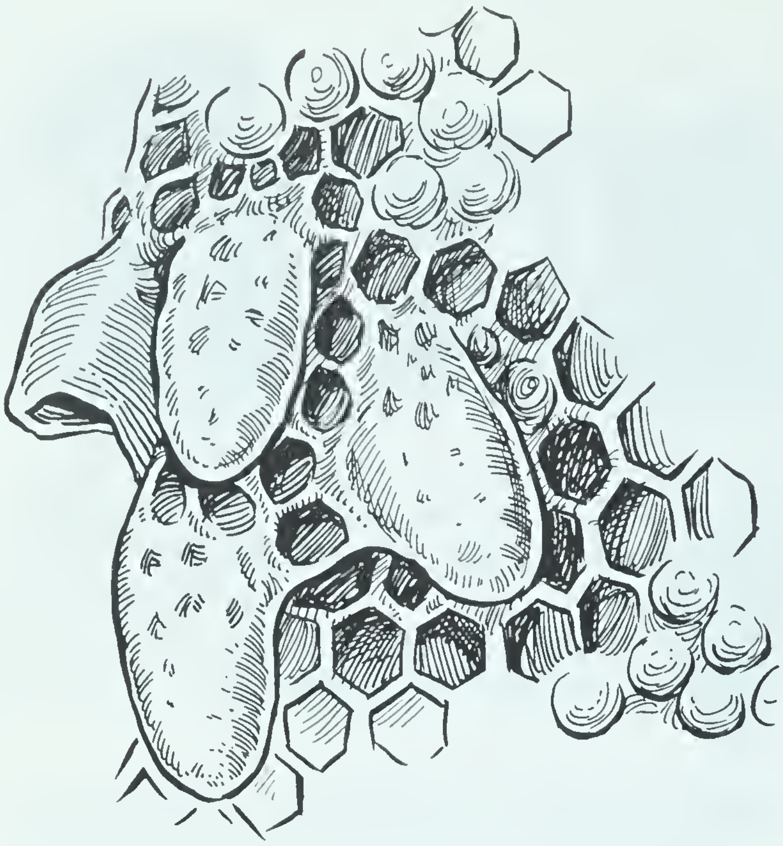


Fig. 18-18. The queen cells may be recognized by their large size.

Bee-keepers in western Canada usually import their bees in packages from the United States each spring. Two and three-pound packages are very popular. The two-pound package contains a mated queen and about 10,000 worker bees. Bees should arrive before May 10 at the latest. Upon arrival, the bees should be fed by spraying or sprinkling a warm sugar solution on the screens. Then the bees may be installed in the hive.

The aim of the bee-keeper must be to keep his colonies fairly strong and to take precautions against swarming. The best colony is one which develops gradually, reaching its greatest strength early in July when the main honey flow begins. The methods a bee-keeper uses to achieve this objective can only be described here briefly in very general terms.

The colony requires a large amount of water, especially during spring brood rearing. If a clean natural water supply is not available, it should be supplied.

Various diseases may attack bees. Hence the bee-keeper must be sure to keep the hives and equipment clean at all times. He must also examine the hives at intervals in order to detect early signs of disease.

One of the hazards of bee-keeping is *swarming*. This must be prevented, if at all possible. The largest honey crops are obtained from strong colonies that do not swarm. Swarming may be caused by crowding, lack of food, or inadequate ventilation. The swarm is that part of the colony which leaves the hive, consisting of the old queen and her protectors. Preparations for swarming may be detected by the presence of eggs in the queen cells in the brood chamber. Another indication is a tendency for bees to cluster at the hive entrance, a sign that the hive is too hot. What steps may the bee-keeper take to prevent swarming? If he feels that the hive is crowded, or likely to become so, he may add extra brood chambers and extra supers. More ventilation may be provided by removing the entrance reducers. Shade, especially in the afternoon, is desirable. Old and failing queens should be replaced by young vigorous queens. If these preventive measures fail, and the colony is still preparing to swarm, it may be advisable to destroy all queen cells and to clip the queen's wings.

Some bee-keepers winter their bees in dark, cool, ventilated cellars or in special cases out-of-doors. If this is done, the bees must be supplied with extra food, such as sugar-syrup or

honey. Many bee-keepers prefer to kill their bees each fall and start again in the spring with new bee packages.

Bee-keeping is a very interesting hobby. It may prove to be quite profitable as a side-line. But beginners are advised to begin on a small scale, with one or two hives, until they gain the necessary experience.

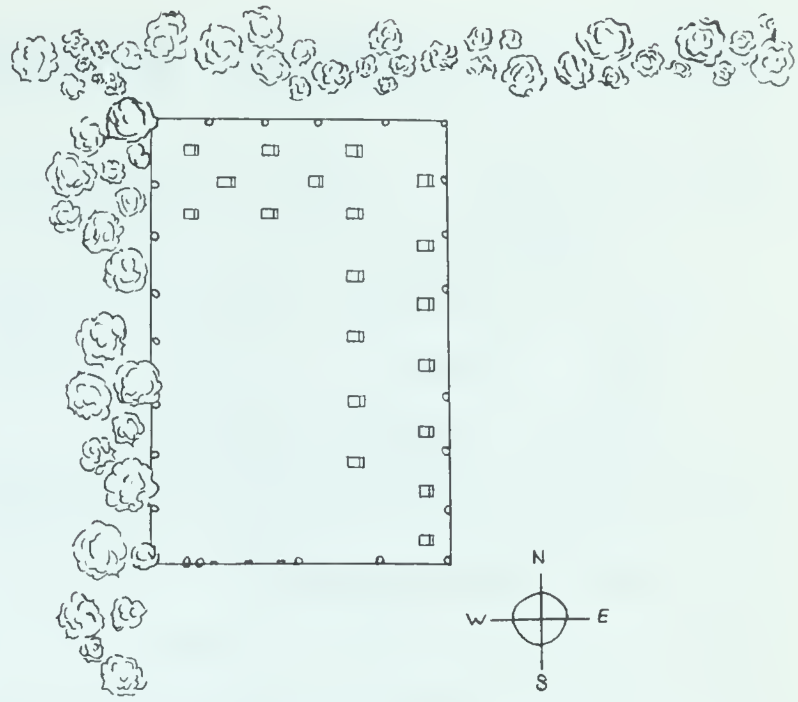


Fig. 18-19. A well-located apiary is sheltered from the prevailing winds.

REVIEW QUESTIONS

1. Name three ways in which bees are useful. **2.** Why are bees called social insects? **3.** Describe briefly the three types of bees found in a colony. **4.** What is royal jelly? **5.** Name ten plants that are important sources of nectar. **6.** Describe briefly the Langstroth type of hive. **7.** What is meant by an apiary? **8.** Name three probable causes for swarming. **9.** What may be done to prevent swarming? **10.** Why should a beginner in bee-keeping start on a small scale?

QUESTIONS FOR REVIEW AND DISCUSSION

1. What is an "order" of insects? Name six orders based on the kinds and numbers of wings.
2. State five good reasons why insects are so numerous.
3. Describe the life history of the grasshopper. In what stage does the grasshopper do the most damage?
4. What are the main characteristics of a good insecticide?
5. In what ways may garden control of insects differ from field control?
6. Describe the injury done by each of the following insect pests:
   (1) Aphids (3) Cabbage Worm
   (2) Flea Beetles (4) Potato Beetles
   (5) Wireworms
7. How is shellac made?
8. What damage is done by the larvae of the (1) clothes moth? (2) the carpet beetle?
9. How is malaria spread? Name two other diseases spread by insects.
10. Describe how the housefly spreads disease germs. What precautions may be taken to protect our food from the housefly and to reduce the number of houseflies?
11. How does a bee make honey?

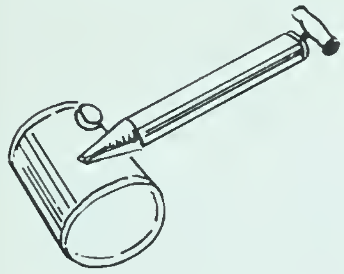
SPECIAL REPORTS AND PROBLEMS

1. Report on a field trip you have made to study insects.
2. Make a collection of pictures showing insect damage to trees, clothing, flowers, vegetables, field crops.
3. Prepare a chart showing the difference between complete and incomplete metamorphosis.
4. Make a collection of moths and butterflies.
5. Report on the insect collection in a museum that you have visited.
6. Report on the interesting life cycle and migratory habits of the Monarch Butterfly.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of: metamorphosis, thorax, spiracles, larva, pupa, cocoon, contact poison, stomach poison, royal jelly, lindane, sucking mouth parts, biting mouth parts, swarming, seed dressings, bait, insect traps, protective coloration, parasitic insects.
2. Each statement below is descriptive of an injurious field insect in western Canada. Indicate the insect described in each case:
   (a) The adult is a night flying moth called a Miller.
   (b) The larvae live in the soil for many years.
   (c) This insect can be controlled by spraying the young crop with chlordane as soon as damage is noticed.
   (d) Infestations may be prevented by cultivating the soil until August 1, after which the surface is left undisturbed till September 15.
   (e) The adult is a wasp-like insect, black in color, with yellow bands on the abdomen and yellow legs.
   (f) The larvae damage the germ of the seed when it is planted and destroy the central part of young plants.
   (g) Plants are cut off at or just below the surface.
   (h) When a fallen wheat stem is cut open lengthwise, *sawdust* is found inside the stem.
   (i) The adult is a black beetle which, when placed on its back, jumps into the air with a distinct click.
3. With reference to the control of insects, distinguish between: natural control, chemical control, cultural control.
4. List various forms of losses and damages caused by insects. Does it pay to spend large sums of money on insect control? Explain.
5. What are entomologists? Describe the important work done by entomologists.

The old

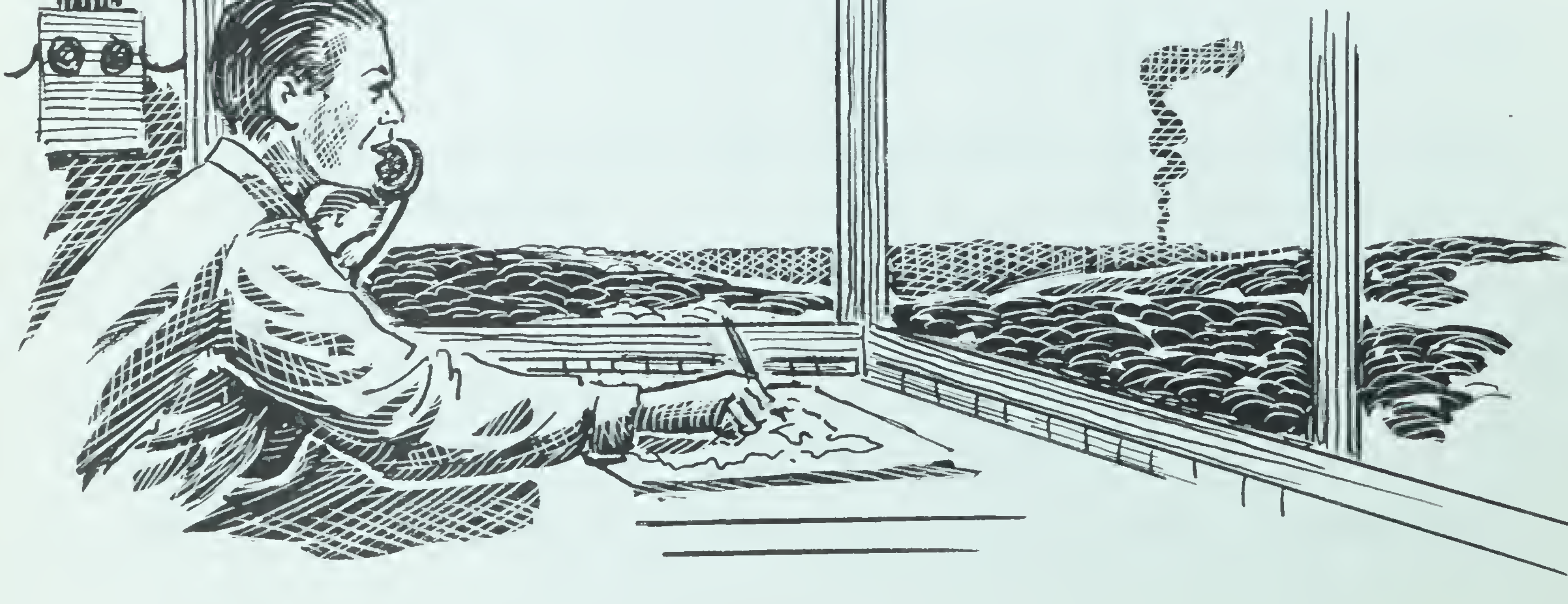


THE EARLY SETTLER ON THE WESTERN PLAINS FOUGHT insects only as the need arose. Scientific methods of protection, prevention, and control were not known to him. A few standard poisons, mainly compounds of arsenic, were used over and over again regardless of the type of insect.

The new

TODAY THE SCIENCE OF INSECT STUDY, KNOWN AS entomology, is highly organized. The federal government has established laboratories across Canada. Insects are under constant study by well-trained scientists. New methods are being developed that stress prevention as well as control. Bulletins and booklets are published advising the farmer how to protect his crops. Entomologists and research chemists co-ordinate their work to formulate new, effective poisons that are safe to use for specific purposes. Experiments are conducted with insect parasites and, in the future, it is expected that the use of parasites will become a very important factor in controlling insect pests.

The student who is interested in nature should consider a career in entomology. Such work brings great satisfaction, as the entomologist is aware that he is helping to promote increased production, as well as preserving the beauties of our gardens, orchards, and forests. Perhaps most rewarding of all is that the work of the modern entomologist often takes him out-of-doors, where he may conduct his researches among the wonders of nature.



UNIT 19

How has man learned to grow and protect crops and forests?

DISCOVERY AND PROGRESS

AT first the settlers on the prairies used farming methods that had proved satisfactory in the older areas of the east. They soon discovered that ideas had to be changed and farming practices modified. As the line of cultivation spread west and north new problems, brought about by the shorter growing season, plant diseases, and insect pests, had to be solved.

Governments, seed-growers and scientists came to the aid of the western farmer. The federal government established Experimental Farms and Stations across the west to carry on research in all phases of agriculture. Universities embarked on programs of soil testing and plant improvement.

Agriculture is much more scientific today than in the time of the pioneer. Science is teaching man how to adapt himself to new environments. One result has been greatly increased production.

Plant breeders have taken a leading part in the progress that has been made. Red Fife, the variety of wheat grown by the pioneers, was replaced by Marquis (1909). Marquis wheat, being earlier and higher yielding, was the scientist's answer to the hazard of early frost. Later (1934), the Minnesota Experimental Station developed Thatcher, a rust-resistant wheat. Thatcher became the successor to Marquis and has saved western farmers millions of dollars. Recently (1953), the Laboratory of Cereal Breeding, Winnipeg, has released Selkirk wheat, which is resistant to rust race 15B. Other important varieties of wheat have been developed by scientists for various purposes.

Wheat is the major crop of the plains region. However, the emphasis has not been on wheat improvement to the exclusion of other grains. New varieties of oats, barley, rye, and flax, have been released for distribution. Experiments are being conducted with foreign and native grasses with the object of improving forage crops.

Implement designers have developed farm machinery to speed up tillage operations and to reduce costs. Within the last few generations, the binder has been largely replaced by the swather and the combine; the ox has been replaced by the horse; and the horse, in turn, by the truck and the tractor.

The first settlements in western Canada were established on the banks of prairie rivers. Here the pioneers were able to obtain fuel and water. They soon found an abundance of native edible fruits, such as strawberries, raspberries, currants and saskatoons. Three kinds of cherries—the pincherry, chokecherry, and the sandcherry—were widely distributed. In northern districts, the settlers gathered cranberries and blueberries. Encouraged by this, farmers and horticulturists have developed many varieties of cultivated fruits suited to the western climate.

As settlement moved northward, prairie people became more aware of the great forest resources. The development of these "prairie" forests will bring great wealth to western Canada. But to prevent loss and waste, emphasis must be placed on scientific management. As with our soil resources, scientists are continually improving methods of conservation. Progress has been made in controlling forest fires, in combatting insect pests and plant diseases that attack the trees. Selective cutting and reforestation techniques are applied. Such measures bring slow returns, but with careful management forests can be made to yield continuously through periods centuries long.

QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What are the main cereal and forage crops of western Canada? **2.** Why are grass-legume mixtures grown? **3.** How can we destroy winter annuals? **4.** What is 2,4-D? **5.** What types of cultivated fruits may be grown in the prairie region? **6.** What is a scion? **7.** Why do fruit trees require shelter? **8.** How may a specific variety of fruit be propagated? **9.** What are the causes of forest fires? **10.** What tree is the most valuable in the commercial forest area?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

blade weeder .... machine having slanted blades which penetrate the soil slightly and cut off weeds.
deciduous trees ..... (de-*sid*-u-us), trees that lose their leaves in autumn.
forage crops .... crops used for feeding livestock.
herbicide .... a chemical compound used to destroy plants.
hybrid .... the offspring of two parents of different varieties.
propagation .... the act of reproducing.
reforestation .... to renew a forest by seeding or planting.
scarification .... the process of making scratches on seed coats.
smoke jumpers ..... parachutists who investigate smoke and fight fires in forested areas.

A What are the essential field crops of western Canada?

There are many varieties of crops grown in western Canada. The type of crop produced in any particular area depends upon the kind of soil, local climatic conditions, distance from market, the system of farming (mixed or specialized), and other factors.

The main field crops of the prairies may be classified according to *use* as follows:

Cereals—members of the grass family used for food: wheat, oats, barley, rye.

Forage crops—pasture and hay crops used for feeding livestock: grasses, millet, legumes, corn.

Oil crops—oil is extracted from the seeds to be used for various purposes: rape, flax, soy-beans, sunflowers.

Root crops—used for feeding livestock and, in case of sugar beets, for sugar: turnips, sugar beets.

The above classification is not rigid. For example, flax is sometimes classed as a cereal; soy-beans are bushy legumes that may be grown for use as a feed for livestock or to yield oil.

B What are the cereal crops and how are they grown?

The most important cereal crop in Canada is wheat. Most of this crop is grown on the western prairies. Perhaps

Fig. 19-1. Often the wheat is cut just before it ripens and is left lying until it is dry enough to be threshed.

Fig. 19-2. Thatcher wheat (left) and Selkirk wheat (right) were developed to resist rust.

you will wonder why western Canada has gained a world-wide reputation for growing wheat of excellent quality. Good soil and especially favorable growing conditions, such as the spring rains, the hot summer, and the cool fall, combine to produce a hard kernel that makes bread of superior quality.

In the West, the main wheat crop is *spring wheat*. That is, the seed is sown in the spring and the crop is harvested in the fall. Spring wheat requires a well-drained, fertile soil, rich in nitrogen and phosphorus.

The seed should be clean and pure. The variety of wheat grown should be one that is recommended by agricultural authorities for the particular district.

Before the wheat seed is sown, it should be tested for germination. Only wheat seed of high germination should be chosen. The seed should be treated with the necessary chemicals as a protection from smut and to discourage wireworm damage (see Unit 18 on insects).

Wheat should be sown early in the spring at the rate of one to two bushels per acre. Early sowing helps to reduce the danger from rust and early frosts.

Wheat that has reached full maturity is often harvested by means of a *combine*. This cuts and threshes the grain in one operaton. But usually the crop is *swathed*; that is, it is cut just before it ripens and is left lying on the stubble in windrows until it is dry enough to be picked up and threshed by a combine. The grain should always be swathed if weather conditions are unfavorable or if there is sawfly damage. Another method of harvesting, still in use in parts of the prairies, is to cut the wheat with a *binder*, and arrange it in stooks consisting of eight or more sheaves. When the stooked grain has dried and ripened sufficiently it is run through a threshing machine.

There are many varieties of wheat. Scientists have developed different varieties for certain areas and for specific purposes. Thus, *Selkirk* Wheat has been developed because it is resistant to a new race of rust, known as 15B. *Chinook* is resistant to sawfly and should be grown in areas (if recommended by the authorities) where that insect is likely to be present in great numbers. *Lake* is suitable for dry areas, as it is resistant to drought. *Thatcher*, *Redman*, and *Lee*, are also popular varieties.

Durum Wheat is a special class of bearded spring wheat. It is used for making macaroni and spaghetti. *Stewart* and *Pelissier* are two leading varieties of Durum.

Oats are another common cereal crop. They are used chiefly for feeding livestock. The oats may be used as feed in the form of whole or chopped grains, sheaves, or silage. Also certain breakfast foods, such as rolled oats, are manufactured from the kernel of the grain.

Oats are produced in much the same manner as described for wheat. However, they require more moisture than wheat and grow best where rainfall is abundant. The rate of seeding may vary from one and one-half to three bushels per acre.

Barley is a very useful cereal. For instance, it is an excellent feed for fattening livestock. The reason for this is that the barley kernel contains a high percentage of *carbohydrates.* Carbohydrates, as you know, help in the production of fatty tissues, as well as in supplying heat and energy.

Barley crops reach maturity fairly early. They are harvested before certain weeds have matured, such as wild oats. Hence, by harvesting his barley crop, the farmer is able to destroy wild oats before they scatter seeds. For this reason barley is considered to be a *cleaning crop.*

Fig. 19-3. Oats (shown at left) is used chiefly as forage for livestock and in the production of breakfast foods. Barley (at right) is frequently used in the malting process.

Barley is also used for *malting purposes*, that is, the kernels are used in the process of making beer.

Vantage, Titan, Husky, Montcalm, and *Parkland*, are the main varieties of barley. The latter two are malting varieties.

Rye is a cereal crop that may often be grown on land which is not suitable for wheat production. This is true particularly of sandy soils. Rye, when sown in the fall (fall rye), produces a carpet of growth which withstands wind damage throughout the winter and early spring. Fall rye may also be grown satisfactorily on wild oat infested land, not suitable for wheat. Its rapid spring growth and early maturity make it possible to harvest the crop before the wild oats have developed fully.

Fall rye, that has wintered over successfully, forms excellent pasture in the spring, as it is ready before the native or cultivated grasses. It is often very useful in preventing soil drifting in the fall or spring.

Rye sown in the spring (spring rye) is commonly used as a hay crop.

Rye grain may be ground into flour. Bread composed of from 35-50% rye flour is used extensively in America and Europe. Rye grain is also used in the distilling industry for the manufacture of whisky.

REVIEW QUESTIONS

1. What is the most important cereal crop in Canada? **2.** What is spring wheat? **3.** What are the ideal conditions for the production of bread wheats? **4.** How is seed wheat treated to prevent damage by smut? **5.** What is Durum wheat used for? **6.** Why are oats grown? **7.** State one reason why barley is an excellent feed for livestock. **8.** Why is barley sometimes called a cleaning crop? **9.** Name three uses for rye. **10.** Write a note on the production of fall rye.

C What forage crops are grown in the prairie provinces?

Forage crops are hay and pasture crops. Besides providing excellent feed for livestock, they enrich and conserve the soil, help to control weeds, and place farming on a more stable basis.

More acres in improved forage crops mean greater yield from hay and pasture fields. Thus, more livestock may be raised and the farmer obtains greater returns.

Forage crops add organic material to the soil. Legumes (alfalfa, sweet clover) add nitrogen. The decay of roots and plant material adds fibre to the soil and increases bacterial activity. It has been estimated that a four to five year stand of grass will add three tons of organic matter to the soil per acre.

A farmer who has a good pasture of mixed grass and alfalfa and a good hayfield is able to build up a *reserve of feed* over a period of years. Livestock and feed reserves give balance to farm income and make the business of farming more secure.

Brome Grass and Crested Wheat

Fig. 19-4. Crested Wheat Grass was developed in the prairie region of Siberia. It is very hardy.

Grass are the most useful grasses grown in the prairie region. *Brome Grass* has a very extensive root system, thus adding fibre to the soil. The seed should be sown at a depth of less than one inch, in a firm seed-bed. Brome is an excellent pasture crop. When the grass begins to bloom, it is mowed and raked into small piles to cure. Later it may be stacked and used for hay. In areas where farm labor is scarce, the Brome is raked by a machine into swaths. Then it is picked up by a machine called a baler which packs the hay into bales. The bales are often left in the field to dry to some extent before stacking.

Crested Wheat Grass is noted for its resistance to drought, making it most suitable for the drier areas of western Canada. Crested Wheat Grass makes an excellent early spring pasture. However, in mid-summer there is a tendency for the pasture to "brown." Crested Wheat Grass produces a harder hay than Brome and gets tough and wiry if not cut at the proper stage, which is just at heading time. Harvesting methods are the same as for Brome Grass.

Slender Wheat Grass is a type of perennial grass native to western Canada. This grass is very hardy and grows well in most areas. It is commonly called "Western Rye Grass," and although it is good for general purposes it is better for hay than for pasture. The reason for this is that it

Fig. 19-5. Reed Canary Grass can withstand many days of flooding.

Fig. 19-6. This mount, of Ladak alfalfa (left) and Creeping Rooted alfalfa (right) shows clearly the deep, penetrating roots which add fibre and fertility to the soil.

tends to die out in spots, particularly when trampled by livestock. Slender Wheat Grass is short-lived (about three years) and is susceptible to sawfly attack. It is a valuable crop for alkali soil and for flooded land.

There are many other types of perennial grasses. Among these are Timothy, Reed Canary Grass, Intermediate Wheat Grass, and Russian Wild Rye. *Timothy* is a tall, leafy grass that is readily eaten by livestock. *Reed Canary Grass* is most suitable for low-lying areas that may be subjected to prolonged flooding.

Alfalfa is a long-lived perennial hay crop of high yield. It is not a grass but belongs to the Legume Family of plants, which includes peas, beans, clovers, and caraganas. On the roots of these legumes are tiny *nodules.* Nodules contain millions of bacteria that have the power to take nitrogen from the soil air and make it into a form suitable for use by the plant. This nitrogen is stored in the roots, stems, and leaves. Hence, plants belonging to the Legume Family help to improve the fertility of the soil.

Alfalfa seed is sown early in the spring at a rate of ten pounds per acre. The soil should be firm, moist, and free from weeds. Shallow seeding is important. Before it is sown the seed should be thoroughly moistened in a solution known as a *nitroculture.* This solution contains bacteria and has the effect of encouraging rapid, vigorous growth.

The alfalfa crop is cut when about ten per cent in bloom. When the plants have dried slightly, they should be raked into small mounds. Care must be taken to prevent excessive drying, as the leaves will fall off. The leaves are the most nutritious part of the

plant and every precaution must be taken to prevent leaf loss. On the other hand, if alfalfa is stored away too damp, it will heat and spoil. Therefore good judgment must be used regarding the proper time for storing or stacking the hay crop.

Ladak and *Grimm* are two varieties of alfalfa recommended for the prairies.

Alfalfa is rich in protein and is a very valuable hay crop. As protein promotes growth and milk production, alfalfa is a particularly good feed for young growing stock and for dairy cattle. However, there is a danger in using pure alfalfa for pasture. Alfalfa frequently causes bloating in livestock. For this reason it is preferable to use grass-legume mixtures, as described later in this Unit.

Sweet clover is a valuable feed similar in many ways to alfalfa. Sweet clover is a biennial. That is, it lives for only two years and produces one crop. Its chief advantages are: high yield, high quality hay and cheap seed.

There are two kinds of sweet clover, white blossom and yellow blossom. Yellow blossom is a little better for pasture and the white blossom is a little better for hay.

Like alfalfa, sweet clover is a member of the Legume Family. It stores nitrogen and has almost as much protein content as alfalfa. It is winter hardy, drought and alkali resistant, but it can only withstand about one week of spring flooding.

The methods of sowing and harvesting sweet clover are similar to the methods used for alfalfa. However, besides treating the seed with a nitroculture, it must be ***scarified*** in order to hasten germination. The scarification process consists of passing the seed through a machine that scratches the hard outer coating.

As with alfalfa and all other legumes, there is some danger of sweet clover pasture causing bloating in cattle, especially if the pasture is fresh and lush.

Red clover is a short-lived legume that is used extensively in eastern Canada as a hay crop. *Alsike clover* is a short-lived perennial clover that is useful on flooded land.

Wherever possible it is advisable to grow a grass-legume mixture. Alfalfa is the legume most frequently used in mixtures, although sweet clover and other clovers may also be used under certain conditions. Compared to grass, sown alone, a grass-legume mixture produces a better balanced feed and is higher-yielding over a period of years. *Grass-alfalfa mixtures* are superior for enriching the soil. The mixture, cut for hay, is more easily cured and there is less danger of the cattle bloating than with the legume alone. Three common mixtures are: Brome-alfalfa; Crested Wheat Grass-alfalfa; Crested Wheat Grass-Brome-alfalfa.

Corn is a forage crop that is grown in many parts of the prairies. It may be sown in rows 36 inches or more apart with an ordinary grain drill. Twenty to thirty pounds of seed are required per acre. When a corn planter is used the rate of seeding may be reduced.

Corn should be harvested as soon as there is danger of frost. The crop may

Fig. 19-7. This farmer is mowing a Brome-alfalfa mixture. What are the advantages of growing mixed crops of grasses and alfalfa?

be cut with a corn binder or an ordinary grain binder. The sheaves may be stacked or left in the stook. Another method of harvesting is to use a mower, leave the mown corn to dry, and then stack it between alternate layers of straw.

Corn makes a very successful feed for livestock, either straight from the stook or from the silo. In some parts of the prairie provinces grain corn is harvested. The ripened ears are stored in well-ventilated bins, and are used for feed.

REVIEW QUESTIONS

1. List three uses for forage crops. **2.** Name three forage crops grown in the prairie region. **3.** Why do dairy cattle and young stock require protein? **4.** Why is sweet clover seed scarified before it is sown? **5.** Why is alfalfa seed inoculated? Explain the process briefly. **6.** State the advantages of growing grass-legume mixtures. **7.** Describe Brome Grass and Crested Wheat Grass. **8.** Describe the root system of alfalfa.

D What are the chief oil and root crops?

In western Canada flax is grown chiefly for the seed. From this seed linseed oil is extracted. This oil is used in the manufacture of linoleum, paints, and several other products. After most of the oil has been removed, the remainder of the seed may be used as *oil-cake* for feeding livestock.

Flax is very susceptible to disease, especially to wilt and rust. Therefore the seed should be treated, before it is

Fig. 19-8. Flax seed, which matures in bolls like this, yields oil which is used in the manufacture of many products.

sown, with a mercury fungicide. Precaution must also be taken not to have one crop of flax following another on the same field, as many flax diseases over-winter on the straw. *Rocket, Redwood*, and *Victory*, are disease-resistant varieties of high oil content.

Rape is an oil seed crop that is becoming popular in some areas. It is grown in various parts of northern Saskatchewan on certain types of soil. The oil is used in the manufacture of margarine and other products.

Soy-beans also yield oil for many purposes. Soy-beans are legumes, with hairy pods and stems. Each pod produces about four beans, on the average. One use for the oil, extracted from the beans, is in the manufacture of margarine. After the oil has been removed, the residue (oil-cake) is used as a feed for livestock.

Soy-beans are sometimes used as a hay or pasture crop. They may be mixed with other grain, such as corn, to produce silage.

Most of our sugar is now produced from sugar-beets. These beets are long, tapering, silvery roots, containing about 18 per cent sugar content. When the beets are brought to the factory, they are cleaned thoroughly, and sliced into thin strips. Hot water is used to dissolve the sugar from the strips. The sugar solution is then filtered, and later boiled until sugar crystals form. The pulp, residue from the extracting process, is used for feeding cattle and sheep. The sugar-beet tops, cured or as silage, may also be fed to livestock.

Sugar-beets have a high water requirement, and it is important that the crop be well supplied with moisture throughout the entire growing season. For this reason, sugar-beets grow best in areas of heavy rainfall, such as in certain areas of Manitoba, and on irrigated land in Alberta. Sugar-beets have been the most profitable field crop grown on irrigated land in Alberta during the past ten years (40,000 acres in 1952). The cultural methods described below are the ones in use in that province.

The land should be cultivated in the fall after harvest and again in the spring. It must be levelled and worked into a fine condition, with no lumps larger than marbles. The final seed-bed should be quite firm and have ample moisture within one inch of the surface.

The most popular varieties of sugar-

beet seed in Alberta are Kuhn (of Dutch origin) and S.D.E., a British improvement of a European variety. The seed is sown in late April or early May. Ammonium phosphate fertilizer is often applied directly with the seed.

Immediately after seeding, weeding must begin. A special implement, known as a finger weeder, or some similar implement may be used. Care must also be taken to thin out the crop, mechanically or otherwise, until there are about 100 beets per 100 feet of row.

Irrigation should begin in the spring, after thinning, and should be repeated at two or three-week intervals. The last irrigation should be planned to leave the soil moist for harvesting. Not only does this make harvesting easier, but it improves the yield and storing quality of the beets.

Harvesting takes place at the end of September or during October. The beets are lifted from the ground and topped. Machines for harvesting purposes have been developed and have reduced costs substantially. The harvested beets are hauled to local loading stations whence they are delivered to a sugar factory.

REVIEW QUESTIONS

1. Name three oil crops that may be grown in western Canada. **2.** What use is made of flax seed produced on the prairies? **3.** Why is western flax not suitable for the manufacture of linen? **4.** Name two hazards to which flax is especially susceptible. **5.** What use is made of rape seed oil? **6.** What is oil-cake? **7.** Describe the growing of sugar beets. **8.** Name two uses for sugar beets.

Fig. 19-9. Annual weeds, such as Lamb's-Quarters, usually scatter their seeds before the crop is harvested.

E What losses to the farmer are incurred by weed growth?

A weed is any plant growing in cultivated ground to the detriment of the crop. Most weeds are wild plants, economically useless, or unsightly. Losses, due to weeds, on the farm are greater than those caused by insects and plant diseases combined.

The climatic conditions of the prairie provinces, so suitable for the production of the very best wheat, are also favorable to the growth of many weed species. Due to the lack of intensive cultivation, many perennial weeds thrive. Annual weeds are also abundant because their seeds mature

Fig. 19-10. The Stinkweed is a pest to the prairie farmer. What help does he have in identifying such weeds?

before the time of harvesting most of the grain crops.

The most important method of control is prevention. Many almost hopeless situations could have been avoided had the farmer recognized certain weeds earlier. Most perennial weeds can be eradicated cheaply, if caught in time. Once an infestation gets out of hand, however, eradication may cost almost as much as the land is worth. The pressing problem is to prevent such a situation. There are certain general recommendations which will assist. Among these are the following: Sow only clean seed. Thoroughly clean harvesting machinery before moving from one field to another, so as to avoid spreading weed seeds. Do not leave weed seeds and other refuse from sifting operations on the ground. Control the weeds on uncultivated ground by mowing them down, or applying a suitable weed spray along fence lines and road allowances, in slough bottoms and around the barnyard. Mow around the outside of each crop field at least twice during the summer.

It is easy to learn to recognize dangerous weeds, yet it is astonishing how many people fail to do so. Literature dealing with weed problems, most of it well illustrated, is issued from time to time in all three prairie provinces. These pamphlets may be obtained from Provincial Departments of Agriculture. There should be one or more in every farm home. A splendid bulletin for students, *An Illustrated Guide to Prairie Weeds,* has been published by the North-West Line Elevators Association, Winnipeg. In it, sixty-three different weeds are illustrated and described. Farmers may obtain this bulletin free of charge. Weeds which cannot be identified should be taken to the local Agricultural Representative, or sent to the nearest Dominion Experimental farm, or to the Division of Botany, Dominion Department of Agriculture, Ottawa.

PUPIL ACTIVITY

Make a collection of the most destructive weeds in your district, when they are in bloom. Press two specimens of each between layers of newspapers, covered with a wide board, and weighted with a heavy rock. After two days, remove the specimens and place them again in the press between sheets of dry paper. Now, let them remain in the press for at least a week.

Number all specimens which you cannot properly identify. Send one specimen of each to the Division of Botany, Dominion Department of Agriculture, Ottawa. No postage is required. Be sure to keep a numbered duplicate specimen of each one submitted.

Mount each specimen on a sheet of cardboard, (see Fig. 19-11). The recommended size is 11½ x 16½, although smaller sheets are quite satisfactory. Proceed as follows: With a brush apply glue to the backs of the leaves and flowers and attach to the center of the sheet. Secure the stems in place by using narrow strips of Scotch tape. Attach gummed labels, size 2 x 4 inches, to the lower right-hand corner of each sheet. These should contain the information shown on the accompanying illustration. If possible, include the scientific name. Common names are often

Fig. 19-11. Specimen records like the above aid greatly in identifying weeds.

Fig. 19-12. What damage is done to crops by weeds such as the Canada Thistle?

very misleading, and do not give positive identification.

Common Name ....No............
Scientific Name ....
Locality ....
Date ....
Collector ....

Specimen Record

The damage done by weeds may be classified under three main headings. (1) They cause a decrease in crop yield. The reasons for this are that they use up great quantities of *water* and *food materials*. For every pound of dry matter produced, the weeds require at least 500 pounds of water. They rob the soil of valuable phosphates and nitrates. Early weeds often shut off *light* from the young crop. Many weeds also reduce yields by harboring insects and crop diseases. (2) They increase the cost of production. Labor and machinery costs

rise, due to the extra cultivation required. Weeds increase the bulk to be harvested. *Dockage*, that is, deduction of a percentage of the weight of a load of grain due to the presence of weed seeds, may result in a loss up to ten per cent, or more, of the weight of the marketed grain. Freight charges must also be paid to carry tons of weed seed to terminal elevators. (3) They decrease the value of the farm and its products. Not only is the selling price of the farm per acre lessened, but the income from seed grain, hay, and wool, is reduced considerably.

Fig. 19-14. Some weeds, such as the Flixweed, can be either annuals or winter annuals.

F How are weeds grouped for the purpose of control?

A general knowledge of habits of growth is necessary for effective control. One should determine whether a weed is an annual, a winter annual, a biennial, or a perennial. ***Annuals*** reproduce from seed only. Their seeds germinate, and the plants grow, produce flowers and seeds, and die, within the year. Some common examples are: Wild Oats, Russian Thistle, Wild Buckwheat, Stinkweed, Wild Mustard and Red-root Pigweed.

Fig. 19-13. Green Foxtail Grass, at left, is an annual. Wild Barley, at right, is a perennial. Why is it useful to a farmer to know whether a weed is annual or perennial?

Biennials do not produce flowers during the first year. Instead, they build up a reserve food supply in their thick fleshy taproots. During the second year, they reach full maturity and produce seed. Only a few of our harmful weeds are biennial. Among these are: Burdock, Goat's Beard and Gumweed.

Winter Annuals are similar to biennials, but germinate late in summer, and flower quite early the next season. Many in this group, such as Wild

Mustard and Stinkweed, also grow as summer annuals. Other examples are: Tumbling Mustard, Hare's Ear Mustard and Flixweed.

Perennial weeds are those whose roots, or rootstocks, may live many years, producing new stems each year. They reproduce either by seed, by underground stems (called ***rhizomes*** (*rye*-zomes) or root-stocks), or by horizontal roots. They are the most difficult type of weed to eradicate. Some of the most persistent and destructive are: Perennial Sow Thistle, Canada Thistle, Couch Grass, Field Bindweed, Russian Knapweed, Toadflax, and Leafy Spurge.

Fig. 19-15. The Red-root Pigweed is an annual. How do farmers control the growth of annual weeds?

G What are the general recommendations for control of various types of weeds?

There are several distinct methods recommended for the control of annuals, winter annuals and biennials. (1) Seed production should be prevented whenever possible, and seed germination encouraged in the fall and early spring. Frequent surface tillage during late April, May and early June will promote early germination of seeds and kill the seedlings, before the crop is planted. This is particularly important where winter annuals and biennials are abundant. Shallow after-seeding tillage is sometimes practised shortly after the grain seeds have sprouted. Seeds of winter annuals germinate in the fall and the plants will soon become well established. Mustards, of all sorts, are the most common weeds of this type. If the ground is not to be plowed, and there is a heavy growth of these weeds, shallow after-harvest tillage should be used to kill such plants as well as to encourage germination of as many of the weed seeds as possible, before the cold weather sets in. Blade weeders and wide-sweep cultivators are best for this work.

(2) Early maturing grain crops, particularly barley and rye, will greatly assist in controlling these weeds and preventing weed distribution. These crops mature before many weeds, and are cut before the weeds scatter their seeds. These crops are particularly effective for the elimination of Wild Oats. In the park belt, the same results are often obtained by seeding down part of the farm to legumes or grass-legume mixtures, and mowing the field in late June.

(3) Summer-fallow practices are sometimes necessary in order to keep

Fig. 19-16. Wild Oats may be kept under control by sowing early-maturing crops which are harvested before the weeds can scatter their seeds.

weeds under control. The first tillage operation should be made as early as possible. It is important to preserve a trash cover, in order to prevent soil drifting and water erosion. Blade and wide-sweep cultivators are ideal for this purpose, and at the same time will kill most of the weeds. It may be necessary to work the fallow several times during the summer, but the number of tillage operations should be kept to a minimum.

(4) Chemicals are being used increasingly often for the control of many annuals, biennials and winter annuals, as well as perennials. Control by this method is discussed in a later section.

Generally speaking, perennial weeds are more difficult to control than any other types. Most perennials reproduce freely by seed, and this must be prevented as it is with annual weeds. But the prevention of seed production prevents only the *increase* of some perennials. The roots are not killed, and the spread of underground parts is not retarded.

Some perennials, such as Couch Grass and Perennial Sow Thistle, develop long horizontal, underground parts, which extend many feet in a single season, rapidly occupying the ground. These underground parts are of two types—stems and roots. Couch Grass has underground stems. These are called either rhizomes or *rootstocks.* On them, buds are produced at the joints, and scales (reduced leaves) are present. In the case of the Sow Thistle the growths are specialized true roots, called *horizontal roots.* Both rootstocks and horizontal roots serve the same purpose, and both are equally difficult to eradicate. New plants are established when pieces are carried to

Fig. 19-17. Some weeds, such as the Perennial Sow Thistle, are very difficult to eradicate.

other parts of the field by tillage implements.

To destroy perennials, three general methods are available: (1) dig out all underground parts, (2) starve them by preventing weed growth, (3) practice chemical weed control.

1. Whenever possible, patches of perennial weeds should be given special cultivation. If the patch is small, each individual plant may be dug out and destroyed. When machinery is used, care must be taken not to scatter root or rootstock pieces to other areas. For this purpose disc implements are recommended because they are less liable to drag roots to uninfested areas.

2. In order to starve persistent perennials such as Couch Grass, Canada Thistle and Perennial Sow Thistle, it is often necessary to practice an intensive system of tillage, extending over an entire season, from after harvest, and continued until freeze-up the following year. Plowing may be necessary as the first operation on well-established patches.

3. Chemicals used to kill or control weeds are called herbicides. The most effective of these is a compound, commonly called *2,4-D*. This was introduced after years of scientific investigations. The chemical penetrates the plant through its leaves, and is carried to all parts by the plant's circulatory system. The immediate effect is a very rapid, unnatural growth, the nature of which soon kills or greatly injures many plants. The remarkable fact about this herbicide is that it has little or no effect on plants of the grass family,

Fig. 19-18. Weeds that are annuals or winter annuals, like the Wild Mustard, are usually susceptible to the weed-killer 2,4-D.

and so may be sprayed safely on grain crops or lawns.

Some weeds are *highly susceptible* to 2,4-D. Among these are annuals and winter annuals, of which the ragweeds, mustards and Stinkweed are typical examples; biennials, such as Burdock, Goat's Beard and Gumweed; and a few perennials. The common Dandelion is a good example of such a perennial.

Many weeds are only *partially susceptible* to 2,4-D. In some cases several applications are required; in others, destruction results only if the weeds are treated when young. Some annuals in this group are Red-root Pigweed and Russian Thistle. Many perennial weeds, including Sow Thistle, Canada Thistle, Prairie Thistle and Field Bindweed, present a difficult problem. The top

growth may be killed by one application of 2,4-D, but several additional applications are necessary in order to destroy the rootstocks and horizontal roots.

Some very destructive weeds are *resistant* to 2,4-D. Among these are Couch Grass, Wild Oats, Hoary Cress, Russian Knapweed and Toadflax.

There is another herbicide, more recently introduced, known as *M.C.P.* It is recommended mainly for use in crops, such as flax and legumes, which may be damaged by 2,4-D. It will give good control of many common weeds.

REVIEW QUESTIONS

1. What is a weed? **2.** Distinguish between a perennial and a biennial weed. **3.** Distinguish between a biennial and a winter annual. **4.** Mention several of the damaging effects of weeds. **5.** Outline several general methods for the control of annual weeds. **6.** What cultural methods are recommended for the control of Perennial Sow Thistle? **7.** Why is Couch Grass so difficult to eradicate? **8.** Give examples of two annuals, two biennials, and two perennials which may be controlled effectively by the use of 2,4-D.

H What fruits grow successfully on prairie farms?

Western home-makers have succeeded in cultivating many wholesome fruits in their own gardens. It is not expected that the prairie provinces will ever become famous for the quality and quantity of the fruit produced there, yet with the introduction of varieties of extreme hardiness, it is usually possible, now, for a family to produce all they can use.

The pioneers of this country found wild edible fruit in abundance in many areas, which ripened in and about wild thickets, along streams and among the shrubs in the coulees, so common near valleys of the open plains. These berries are still eagerly sought and highly prized. Among them are strawberries, raspberries, gooseberries, red and black currants, Highbush Cranberries, Saskatoons, Buffaloberries, Pincherries, Chokecherries and Sandcherries. It soon became evident that if all of these fruits could survive such a rigorous climate, cultivated varieties, given the proper protection, could be developed by careful selection and breeding. That is exactly what did happen.

Today, except in the arid lands of the southwest where there is no irrigation, on the high altitudes of the foothills of the Rockies, and in the northern parts where the frost-free period is less than a hundred days, farmers can grow successfully crabapples, plums, plum × sandcherry hybrids, red raspberries, strawberries, black currants, red currants, white currants and gooseberries. In addition apples, cherries, and even grapes can be grown in certain areas. Where there is a proper system of irrigation, a great variety of fruits can also be grown on very arid land where previously only short prairie grass and sagebrush predominated.

A tree shelterbelt is necessary for success in the culture of fruit on the prairies. It must be dense and have live branches close down to the ground. The belt may extend on all sides of the garden. If one side be open, it should be the east. There should be a main belt which is made up of several rows of deciduous trees, and a snow-trap which is composed of one or two rows of trees located outside the main belt, and with a space of 125 to 150 feet between it and the main belt. One row or more of evergreen trees should be planted at a distance of not less than twenty feet from the inside row of deciduous trees.

The tree shelter modifies the force of the wind, thus lessening the drying effect and avoiding undesirable snow drifts. Much of the wind is diverted upwards and over the top of the trees. Wind velocity is calculated to be retarded fifty per cent, or more, at a distance equal to ten times the height of the windbreak on the leeward side. Within the windbreak the air is relatively calm. There is a change in humidity and to some extent in temperature. In this sheltered nook, the fruit trees and bushes are protected from both the hot winds of summer and the biting cold winds of winter.

Except where there is irrigation, a fruit orchard or garden is more satisfactory where the land is not level. A gentle slope towards the east and north is considered the best. For strawberries, in particular, the area chosen should be moist but well drained. The plants will not survive if water lies on them. Low spots should be avoided, as cold air settles into such pockets.

For small fruits, irrigation is of value, second only to the tree shelterbelt. Through the assistance of the Prairie Farm Rehabilitation Act, thousands of prairie farmers are impounding a supply of precious snow water in dugouts and behind dams. Such farmers can succeed with fruits to a high degree, as they are able to saturate the earth whenever the soil becomes unduly dry. The Lethbridge area not only has a frost-free period of from 125 to 155 days, but a great deal of the land is under an effective system of irrigation. Here, protected by proper shelterbelts to ward off the severe chinooks, many varieties of fruit trees and smaller fruits can be grown very satisfactorily.

The western provinces are divided into six horticultural zones, some of which are subdivided. Natural variation in growing conditions, in soils, sites, amount of shelter, rainfall, and sharp changes in altitude, all may cause local areas in any zone to be more or less favorable. *Fruit zonation maps* have been prepared for each province, and may be obtained by writing to the Dominion Experimental Farms at Lethbridge Alberta, Morden Manitoba, or Indian Head Saskatchewan. The zonation map for Saskatchewan is also printed in the *Guide to Farm Practice in Saskatchewan*, which may be obtained from any agricultural representative, or from the Extension Department of the University at Saskatoon. To avoid errors in selection of fruit species, the appropriate map and the recommended fruit variety list should

be studied. For the most part, the varieties mentioned in this discussion are hardy in all zones where the common fruits can be grown satisfactorily.

PUPIL ACTIVITY

Obtain a fruit zonation map of the province in which you live, from your nearest Dominion Experimental Farm. Draw this map, making it twice as long and wide as the original one. Color the various zones, marking in at least one town or city in each zone. Within each zone carefully print two recommended varieties of each of the following fruits which will thrive there: crabapple, crabapple hybrid, apple, plum.

Many varieties of hardy fruit trees can be grown over a wide area with marked success, provided that the orchard is properly protected. The land should be well prepared before planting and, preferably, vigorous one-year-old trees should be used. It should be remembered that satisfactory fruit cannot be grown from seed. Named varieties of our common fruits do not reproduce true to variety, from seeds. The increase is brought about by ***budding***, ***grafting*** and ***layering*** or by the use of ***cuttings*** or ***runners***. Only hardy varieties, recommended for each zone, should be started. When planting, the young trees should be slanted at a 60° angle into the 2 o'clock sun. It is important to cover the point of union, where the young tree was budded on the seedling root, with at least two inches of soil. In areas where there is no irrigation or where the moisture supply is likely to be low, wide spacings for fruit trees are desirable. The spacings recommended for average conditions are as follows: apples, crabapples and plums, sixteen to twenty feet; plum × sandcherry ***hybrids***, ten to twelve feet.

Fig. 19-19. This Dolgo crabapple tree is an example of a well-grown prairie fruit tree. Notice the shelterbelt at the left.

Plants of one variety, planted alone, will bear little, if any, fruit. Most fruit trees are self-sterile—that is, the flowers will not set fruit when fertilized with their own pollen. Plants of two varieties, at least, of the same kind of fruit are necessary for fruitfulness, and three or four varieties are preferable. *This is important.*

Crabapples are the most hardy fruit trees for the prairies. Some favorite varieties are *Osman, Dolgo* and *Robin. Columbia, Garnet* and *Beauty* are also grown successfully in Alberta, except in the extreme western zones. *Crabapple hybrids* have been developed by crossing crabapples with apples. Although these are not as hardy as crabapples, the two varieties, *Rescue* and

Trail, are grown in all three provinces.

Few varieties of apples are grown. One variety, however, *Heyer No. 12*, is quite hardy, has been successful in Alberta and, to a lesser extent, in the other two provinces.

Plums have proved very successful in certain zones. *Assiniboine, Bounty, Dandy* and *Norther* are among the favorites. A plum hybrid, called Pembina, is moderately hardy.

Sandcherries were originally native to the prairies and the improved types are extremely hardy. The variety, *Brooks,* is the most satisfactory. Splendid fruits have been developed by crossing the sandcherry with the plum. They are called *sandcherry × plum hybrids*. *Opata, Manor* and *Dura* are grown successfully in all zones except in the foothills and mountains of Alberta.

REVIEW QUESTIONS

1. Describe what is considered the most suitable site for fruit growing. **2.** Tell about the standard type of shelterbelt, recommended for the protection of the fruit garden area. **3.** How are fruit trees propagated? **4.** What precautions should be taken when planting young fruit trees? **5.** Why is it necessary to plant two or more varieties of the same kind of fruit in the same part of the garden? **6.** What varieties of plums are recommended as being hardy in your home area? **7.** What is meant by a sandcherry × plum hybrid? **8.** What other kinds of hybrids are grown in many prairie gardens? **9.** What procedure is considered of value, second only to the tree shelterbelt, for a prairie fruit garden?

Fig. 19-20. The Manor cherry-plum is a hardy bush fruit, suitable for growing in western Canada.

I What small fruits are grown successfully on the prairie?

The strawberry is the most highly prized and most widely grown of Canadian small fruits. Plants should be set out as early in the spring as possible. For prairie farms they should be put in rows four feet apart and the plants set one and one-half feet apart. The trailing stems should be permitted to take root and form new plants at distances of six inches or more from neighbor plants until a matted row is formed about two feet wide. Speaking generally, the most successful culture for the prairie garden appears to be that of taking only one crop from a planting. A new patch is set out each April. A strawberry patch should be mulched with wheat straw or slough

Fig. 19-21. These red currants are ready for harvest. They make delicious jams and jellies.

hay in October for winter protection. The mulching should be done before the ground is frozen hard.

Dunlap is probably the most dependable June-bearing strawberry and *Gem* the best ever-bearing.

Of berry fruits, the Red Raspberry is second only to the strawberry. The location, suited to strawberries, is also satisfactory for raspberries. A gentle slope, so that water and cold air will drain off to lower land, is desired. Northern and eastern slopes are best. Low spots are to be avoided.

Nursery plants should be set out, if possible, before the end of April. In prairie gardens the rows should be eight feet apart. In many districts a winter cover is necessary. Canes may be bent to the ground in late autumn and the tips covered with soil. Except in the northern zones (5 and 6) and in the foothills of Alberta, *Chief, Madawaska* and *Viking* varieties are very satisfactory.

"Bush fruits" is the term commonly used to specify currants and gooseberries. These fruits are especially suitable for making jelly, jam and conserves. The *black currant* has remarkably high vitamin C content, being as much as five times as potent in this important vitamin as oranges and grapefruit.

Since these plants bloom very early, the favorable site is a northern slope which will delay early blooming and prevent damage from late frosts. All currants and gooseberries enjoy a fertile, cool soil that is well drained. Clay loam is preferred to sandy land. The rows are run six to eight feet apart. Plants are set four, five or six feet apart in the rows. As bush fruits are relatively hardy, they are seldom given any special winter protection.

Fig. 19-22. Gooseberries. grow well in cool, sheltered locations.

Some favorite varieties are:
Red Currants: *Perfection* and *Stephens*. White Currants: *White Grape*. Black Currants: *Kerry* and *Climax*.

All of these varieties thrive well in all the fruit zones except the most northerly one (6A), and on the foothills and mountain farm lands of Alberta.

REVIEW QUESTIONS

1. Of the Canadian small fruits, what type is the most highly prized? **2.** At what time of year should strawberry and raspberry plants be set out? **3.** What two varieties of strawberries are highly recommended for prairie gardens? **4.** Discuss two reasons why low spots should be avoided in the small fruit garden. **5.** Tell how strawberry and raspberry plants should be protected during the winter months. **6.** What are the common bush fruits? **7.** Name a recommended variety of each type of bush fruit for your particular zone. **8.** Why is the black currant such a valuable fruit?

J What are some common methods of vegetative propagation?

Vegetative propagation is the production of a new plant from a vegetative part of a parent plant. The vegetative parts of a plant consist of the stem, leaves and roots. Ordinarily, plants are reproduced by means of their reproductive parts, which are the flowers, seeds and fruit.

Vegetative propagation may be carried on in many ways. Shoots may spring up from *underground roots* or from *underground stems* and develop their own root systems. For example, certain poplar trees will spring up at the points where outer roots are severed, and Couch Grass and Canada Thistle will spread all over a garden by means of a system of underground stems or *rhizomes*. A stem trailing on the ground, such as that of the strawberry, may take root at the joints. Such trailing stems are called *runners*. The tiger lily may be reproduced by little bulb-like bodies that grow at the base of the leaves. Many plants, such as lilies and onions, reproduce by ***bulbs***; others, such as gladioli and crocuses, by ***corms***. (A corm differs from a bulb in that the former is solid to the centre, like a potato.) The potato reproduces by specialized underground stems, called ***tubers*** . The dahlia, rhubarb, and peony are commonly propagated by means of ***root division***.

Florists and nurserymen make use of vegetative propagation in the multiplication of their plants. *Stem cuttings* of geraniums, begonias, carnations,

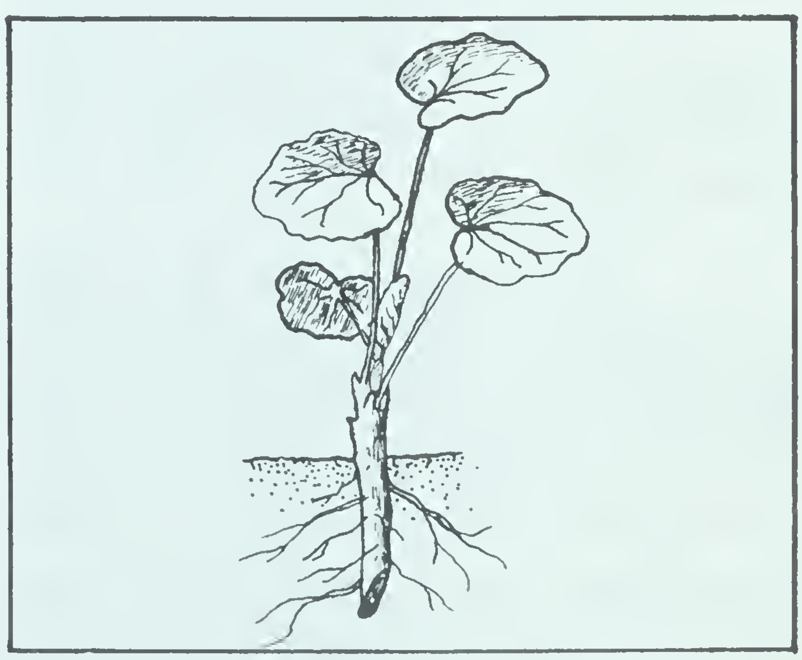


Fig. 19-23. Geraniums may be started from cuttings.

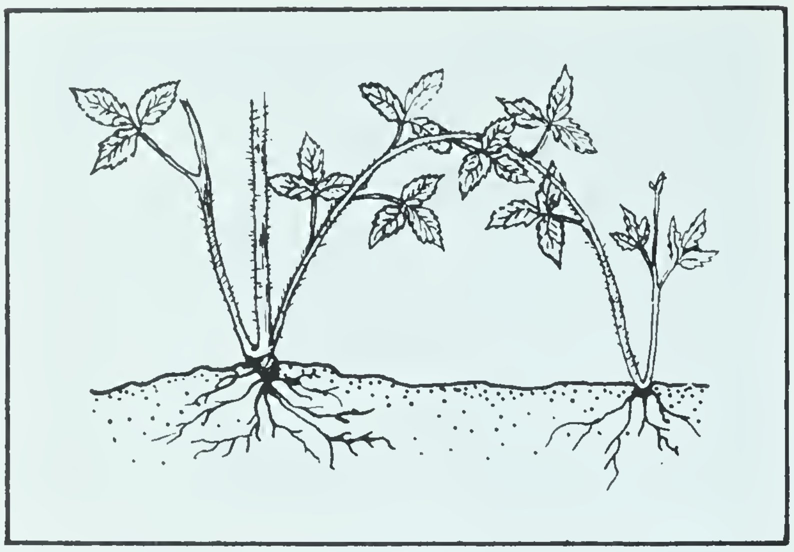


Fig. 19-24. New raspberry plants may be produced by layering.

roses, as well as many varieties of trees and shrubs are set in damp beds of sand, where they develop roots. Raspberries, rose plants and others can be started by *layering*. In this process a branch is pulled down to the earth and partly covered with soil. Soon root systems will develop. The young plants are then severed from the parent plant.

PUPIL ACTIVITY

Fill a container with sand and keep it moist and warm. Obtain slips from geraniums, ivy, coleus and other house plants, and experiment to see how many of these slips will develop a root system. Try also roses and twigs from various trees and shrubs found around the home during the spring months, before the leaves appear.

For the production of fruit trees, propagation by means of grafting and budding is the most important. These trees are hybrids and will not breed true to their characteristics, if reproduced from seed. Therefore, the vegetative method of propagation is resorted to, by which means any variety can be multiplied indefinitely without changing, either by addition or removal, the characteristics which make it desirable.

In grafting, a twig from one plant is set on the stem of another. The twig is called a ***scion*** (sy-un); the stem to which it is attached is called the ***stock***. The essential point in grafting is to set the scion in such a position that the growing layers at the inner edges of the bark will come together. When the two sets of growing cells along the inner edges of the bark multiply, they intermingle and unite the scion and stock.

The raising of trees of a particular variety is accomplished either by grafting a twig or a single bud taken from a tree of the variety required, to a suitable rootstock.

Rootstocks are raised from seed of hardy varieties. For instance, in the prairie provinces, rootstocks from crabapples, such as *Columba* or *Osman* are used for apple production. Sandcherry seedlings are used extensively on the prairies to propagate sandcherry × plum hybrids and cultivated sandcherries of different varieties. When sandcherries are used as understocks for plums, their small root system does not give sufficient anchorage, and the trees may blow over. For this reason plum trees on sandcherry stocks should be planted with graft unions below ground level to encourage scion rooting.

Top-grafting is used to change over the bearing area of a tree from one variety to another. For example, it might be advantageous to grow *Norther* plums instead of *Bounty* plums on a tree already bearing *Bounty* plums. In such a case, scions or buds of *Norther*,

would be grafted on the framework of *Bounty* trees, and eventually, with the complete removal of all Bounty-bearing branches the trees would produce nothing but *Norther* fruit.

Scion wood consists of the terminal shoots, those growing at the end of a branch, which have developed in the latest growing season. The buds should be well developed and the wood well-ripened before the shoots are gathered. Scion wood should be kept in a cool cellar in moist moss or sawdust, unless it is to be used immediately. On the prairies, experiments have indicated that scions cut in late winter or early spring give a better stand.

If directions are followed carefully, the method of root grafting may easily be carried out by any student. All that is needed is a suitable scion, a one or two-year-old seedling, a very sharp knife and grafting wax. Ordinarily, the seedlings are lifted in the fall and heeled-in, in a cool cellar, in moist sand. *Grafting Wax* may be purchased ready for use. It may also be made at home from resin, linseed oil and paraffin, in the proportion of 1 pound of resin, 3 ounces of oil and 5 pounds of wax. Mix the melted resin with the linseed oil and then with the melted paraffin. Pour into a shallow pan and allow to cool in a cake. The amount required may be broken off and melted as wanted.

DEMONSTRATION

Proceed as follows: With the butt of the scion towards you, first make a diagonal cut with a sharp knife so that the face

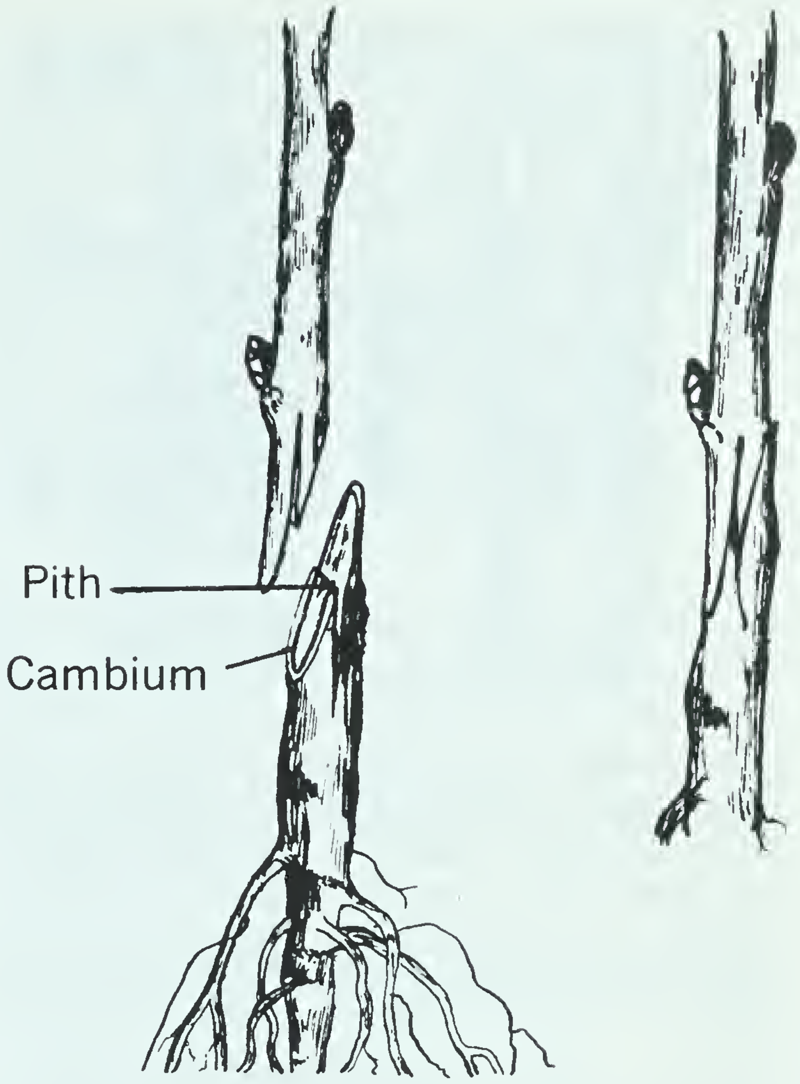


Fig. 19-25. In whip-and-tongue grafting the scion and the rootstock are fitted together to form a tight union.

of the exposed cut surface will be about two inches long. A second cut is now made downward from just above the exposed ***pith***. See drawing. Cut off the top of the shoot just above the third bud.

Next, cut off the trunk of a seedling rootstock just above the junction of the yellow root and the ripe bark, and cut the stock in the same manner as in cutting the scion. The tapered *tongue* of the scion is now inserted into the *cleft* of the rootstock and vice versa, and the two are carefully forced together until they are tightly interlocked. It is absolutely necessary that the bark of the scion and that of the stock be flush on at least one side, for it is along the cambium layer, just underneath the bark, that union takes place. The graft is now tightly bound with No. 16 knitting cotton, previously prepared by dipping the ball in melted

Fig. 19-26. In bud grafting a bud is bound to the rootstock underneath the bark. The Jones budding method, shown above, is most often used on the prairies. **A** shows a bud on a portion of bark; **B** shows the bark flap when the cut is made; **C** is a front view of the bark flap when the top is cut away; **D** shows the bud set into position; **E** shows the completed graft bound with rubber or raffia.

beeswax. The whole joint and the tip of the scion are now coated with grafting wax to seal the exposed cuts, and hold the binding in place. The wax should be no hotter than is necessary to allow it to be applied with a brush.

Trees are often propagated by buds instead of scions. The bud attached to a portion of the stem is called a ***bud-stick***. This is fundamentally the same as scion wood, the only difference being that, whereas scion wood is gathered while it is in a dormant condition, bud-sticks are taken while the tree is still in leaf. They are the terminal shoots which have developed during the current growing season and should be taken only when the buds on them are properly matured. These shoots should be about the size of a lead pencil. After the shoot is cut, the leaves should be removed to conserve moisture, and the top of the shoot should be removed at the first immature bud. Leave about a quarter of an inch of the leaf stem; this serves as a handle when the bud is removed from the stick and again when it is being inserted in the stock. Budsticks should be kept moist by wrapping them in damp moss or sacking, if the budding operation cannot be carried out immediately. Under dry growing conditions, fruit trees are produced more quickly by budding than by grafting. In damper climates, a T-shaped slit is made in the bark. Then the bud, taken from the budstick, is placed in the slit. In the prairie provinces, however, better results are obtained by a method known as the "Jones" budding method, the steps of which are shown in the drawing.

DEMONSTRATION

Proceed as follows: Hold the budstick with the buds pointing towards the body and, starting about ½ inch *below* the base of the bud to be removed, push the knife through the bark, making a downward sloping cut away from the body. Next, starting about ¼ inch *above* the bud, draw the knife under the bud just deep enough to remove a thin shaving of sap wood. Now pull the bud off the stick. (See drawing A.) Now make a downward cut in the rootstock, through the bark and slightly into the wood (B). This cut should be about an inch-and-a-quarter long and one or two inches above ground level. Cut off about half of the bark flap produced by the preceding cut (C). Now insert the bud behind the bark flap and push it well down so that the wedge-cut base of the shield fits snugly into the crotch formed by the bark flap and the stem (D). Bind

in place with a strip of rubber or raffia as shown in (E). Note that the bud is left exposed.

Cleft grafting has been more widely used than any other method to change a bearing area of a tree of an undesirable variety to a desirable one. The graft is made in the spring, about the time when the buds of the trees to be worked over are starting to swell. Only mature one-year-old wood is satisfactory for this type of grafting. The top of the branch to be grafted is removed with a fine-toothed saw. Branches to be grafted must not be larger than two inches in diameter. The scion, cut as illustrated, is inserted so that the cambium layers of scion and branch will come into contact when the cleft is closed. The scion should be given a slight tilt outward. If two scions are used only the most successful one is retained later. The stub is now tightly bound with splicing tape and all parts of the graft coated with grafting wax. (See drawing.) (In the prairie provinces Black-heart disease of the stem may be noted, and in that case this method should not be used.)

The whip and tongue graft is particularly adapted to top-grafting. The method of cutting the scion and stock is the same as for root grafting. Better results are obtained if the scion and branch are about the same diameter. This type of grafting is performed in the spring before, and up to the time of, the first flush of sap. The scion and branch should be bound by tape, and then the binding should be coated with grafting wax. The scion itself, particularly the tip, should also be coated. When the graft starts to grow the tape should be removed.

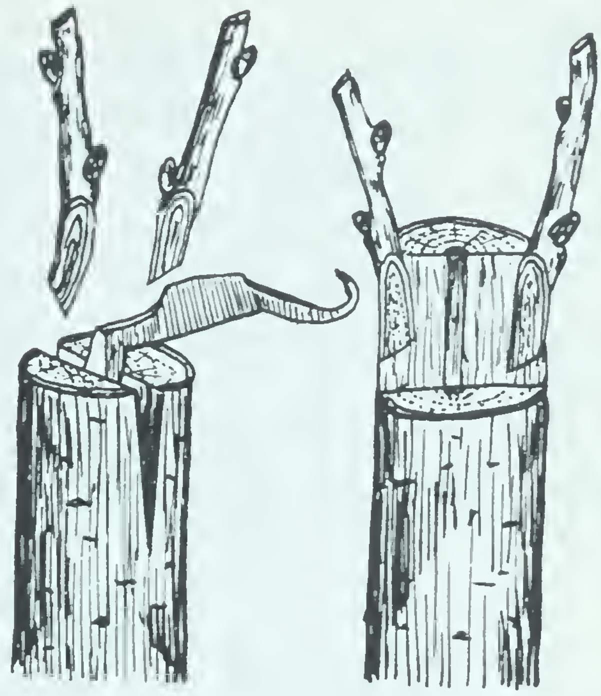


Fig. 19-27. In cleft grafting one or two wedge-shaped scions are inserted into a cleft in the rootstock.

PUPIL ACTIVITY

If you have an orchard at home or even a few fruit trees, try out the various methods of grafting described. Obtain slips of different varieties and graft these on sandcherry seedlings, on crab, on apple and on plum trees. Try some experiments with budding. If done carefully, the results should be very successful. It will be possible for you to grow several varieties of crabs on your crabapple tree and various varieties of hardy plums on your plum tree. Try raising some sandcherry seedlings, and after a year or two a whole series of interesting experiments can be carried out by the use of the rootstocks.

REVIEW QUESTIONS

1. Distinguish between a bulb and a corm. **2.** What is meant by vegetative propagation? **3.** What is a rootstock? **4.** Briefly

distinguish between three types of grafting. **5.** Explain the difference between grafting and budding. **6.** Tell what is meant by a "scion" and a "stock." **7.** Why can fruit trees of a given variety not be reproduced by means of seeds? **8.** In fitting scion to stock in a grafting operation, what special precaution must be taken? **9.** Explain what is meant by a budstick. **10.** How may grafting wax be made?

K What are the forest regions of the prairie provinces?

The greater portion of Manitoba, Saskatchewan and Alberta is covered by forests. A glance at the map will indicate what a very small percentage is prairie or open grassland. Yet, this entire area is known throughout the world as the "three prairie provinces." This is one of the most common geographical errors in Canada today. The reason, of course, is that almost the entire population is concentrated on the area south of the main forest belt. Most of the homes and farms are still on the prairie or scattered throughout the parklands that skirt it on the north.

Our sub-arctic forests are located in what is called the northern transition region. They are south of the arctic tundra and occupy the northern part of Manitoba and the extreme north-eastern portion of Saskatchewan. They do not extend into Alberta. Trees in this area are stunted and shrub-like and are of no commercial value. They do offer a limited amount of protection to the wildlife of the north.

The precambrian forest lies south of the transition zone. On the rough, rocky area of the precambrian shield are the northern coniferous, or evergreen forests. The shield extends only into the extreme north-eastern corner of Alberta. The greater portion lies in Saskatchewan, covering one-third of the entire province. Here *Black Spruce* and *Jack Pine* predominate. These forests are largely inaccessible and at the present time are considered non-commercial though they may prove of commercial value in the future. They are valuable now because they keep the rainwater from running away too quickly and provide a habitat for abundant wildlife.

The mixed forest belt constitutes what is known as the commercial forest area. In Manitoba and Saskatchewan it lies immediately north of the settled area and south of the rocky precambrian shield. It covers most of Alberta north of the prairie and the park area. There are about 93,000 square miles in Alberta, 50,000 square miles in Saskatchewan, and 30,500 square miles in Manitoba. Here our most valuable timber is located. It is divided fairly equally between soft and hardwood species. The most important softwoods are *White Spruce, Black Spruce* and *Jack Pine* with smaller stands of *Tamarack, Balsam Fir* and *Cedar* (Manitoba). The most important hardwoods are *Aspen, Balsam Poplar* and *White Birch. Manitoba Maple, Green Ash* and *Bur Oak* also thrive in certain areas. Most of the oak is in Manitoba.

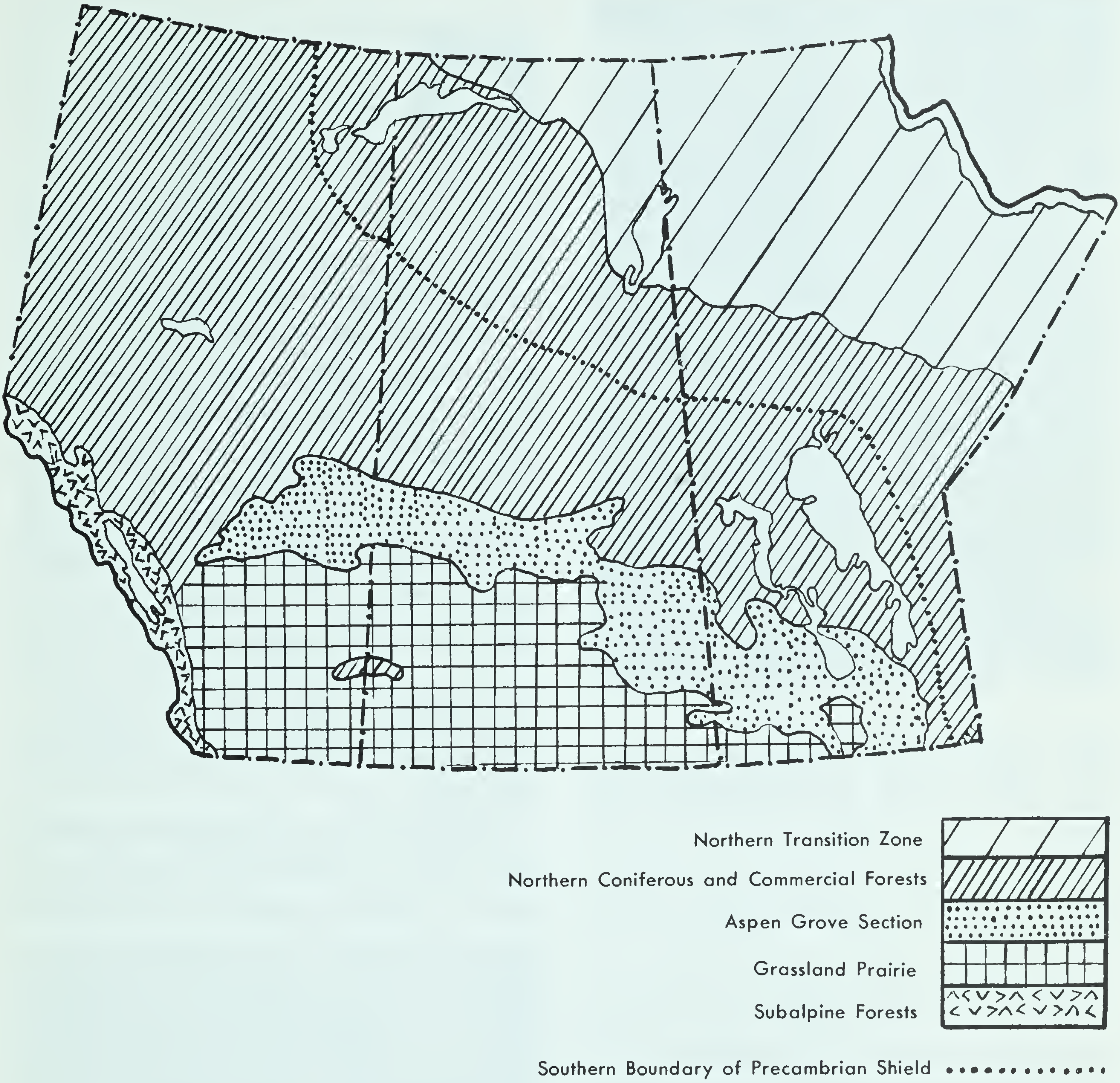


Fig. 19-28. This map shows the forest classifications of the prairie provinces.

This area is still partly inaccessible but is being opened up steadily as development roads are pushed northward. The main commercial stands have been severely damaged by poor cutting practices and fire, but proper management is aiding their comeback. The bulk of the lumber produced comes from White Spruce trees. These trees often grow to heights of more than a hundred feet and have a base diameter up to six feet.

The aspen grove section or the park belt lies between the commercial forest and the open prairies. It is clearly indicated on the map. This area does not produce timber of commercial size, except for fuelwood. *Trembling Aspen* is the dominant tree. *White Elm, Green Ash* grow in certain sections and *Bur*

Fig. 19-29. The White Spruce is one of our most valuable trees. Its great height and girth make it particularly suitable for lumber.

Oak is found in Manitoba and eastern Saskatchewan.

The entire forest region which we have discussed, the subarctic, the precambrian, the mixed forest belt and the parklands, constitute the *boreal forest region*—a region which stretches across Canada from Newfoundland to British Columbia.

The subalpine forest region is another distinctive area. Its characteristics are different from those of the boreal forests. It skirts the mountains near the west border of Alberta. It is essentially a coniferous forest region and produces valuable commercial stands of *Englemann Spruce, Alpine Fir,* and *Lodgepole Pine.*

L What are the values of our forests?

Even with the increasing use of metals and their alloys, wood is still the best material for many uses. The basic forest industry in the prairie provinces has always been the production of lumber from White Spruce. This industry is found in the mixed wood belt across the three provinces. The other principal tree species of commercial value are Black Spruce, Jack Pine, Balsam Fir, Tamarack, White Poplar and Birch, found throughout the entire productive area; Englemann Spruce, Alpine Fir and Lodgepole Pine found in Alberta, and Cedar, growing mostly in Manitoba.

Besides lumber, in its many forms, a great deal of *pulpwood* is being produced. Manitoba leads in this respect but the growing pulp industry in Saskatchewan will soon be of equal importance. Other products which are an important addition to our forest industry are poles for telephone and power line extensions, railway ties, boxwood, mining props, piling, rails, fence posts and fuelwood.

Forests are of value, not only because of the wood they furnish and the employment they provide. They regulate the rate at which water comes off into the streams and rivers, thus preventing soil erosion and serious flooding. This is because the forest floor, consisting of branches, fallen leaves and humus, acts like a sponge. The

water from rain and melting snow is absorbed quickly and is given off slowly. A continuous flow of water is supplied to the streams, even in dry hot weather. The filtered water is pure and cool, thus providing suitable living conditions for fish in the brooks, rivers and lakes.

Forests form an ideal and protected habitat for fur-bearing animals and big game. The fur industry was at one time the most vigorous and remunerative industry in Canada, and it still contributes many millions of dollars annually to the national income. Moose, deer, caribou, and fish of many species attract numerous local sportsmen and tourists, incidentally adding considerably to provincial incomes.

Forest regions form pleasant surroundings for recreational purposes. Thousands flock to these areas each summer to enjoy the cooling freshness, the wild furred and game animals, the birds and the flowers. "How can you

Fig. 19-30. The work of lumbering is made a great deal easier by modern equipment.

estimate the value of a songbird? Or that of a spruce forest wearing its winter mantle of white? Or the value of a stroll through a be-crimsoned September forest? Or that of a two-week vacation in a summer cottage along the tree-lined shore of some northern lake?" These values, perhaps, can be estimated in moral and spiritual measure but not in dollars and cents. And yet, they are just as real and precious as white spruce lumber and power poles.

M What are the most serious enemies of forests?

Man is directly responsible for much of the decrease in forest resources. Farmers have cleared land, only to discover later that because of poor soil or for other reasons it was not suitable for agricultural purposes. Lumbermen have often employed methods that make little provision for the future. When cutting, they have failed to leave a few strong trees to scatter seed, and have made no provision for reforestation.

Fire is the principal threat to our forests. More than 90% of the fires which occur annually are caused by man. The damage is started by camp fires, smokers, settlers, railways, industrial operations, incendiarism and public works. Smokers have been responsible for 20% of the damage, and 16% has been caused by campfires which have been carelessly made or improper-

Fig. 19-31. Many of our valuable forests are destroyed every year by fire due to carelessness.

ly extinguished. Only 19% of forest fires have been caused by natural methods—mostly lightning. On the average, based on a ten-year period, about seven hundred fires have occurred annually throughout the prairie provinces, burning over an area of nearly a million acres and resulting in a damage of $1,700,000. Yet it has been estimated that nine-tenths of this damage could have been prevented.

Forest conservation is the concern of all. Conservation means the using of trees in such a manner that the value of the land as a producing property is maintained. City workers, farmers, trappers, sportsmen and vacationists should bear in mind that our prairie forests are in the driest forest belt in Canada, and that one match can ignite a conflagration that may cause loss of hundreds of thousands of dollars. Two minutes of vigilance is enough to

Fig. 19-32. A parachutist is dropped from a forest patrol plane to investigate smoke that has been sighted. Such a man is called a smoke jumper.

smother a camp fire, and ten seconds will snuff out a match or lighted tobacco.

Effective means are now being put into practice for the control of forest fires. The provinces have developed very efficient fire protection organizations, utilizing aircraft, lookout towers, radio telephone systems, fireguards, road mechanical transport equipment and smoke jumper units. Daily patrols by aircraft, and their use in carrying smoke jumpers, fire crews and equipment to remote fires, enable quick action to be taken and many fires to be controlled before extensive damage can result.

Insects of many species and fungus diseases of various sorts are other enemies of the forests. Some insects feed on the leaves; some insect larvae bore into the bark and wood. Both types cause considerable damage. Fungus diseases cause *blight* and *rot*. To combat these natural enemies, the Provincial Forests Services co-operate with the Federal Division of Forest Biology, who maintain staffs for this purpose. The most effective means of control of insects is through their natural enemies, such as birds and certain parasitic insects. Spraying forest trees for the control of insects and fungi is not practicable, as it is in orchards or around the home.

Provision should be made for the future. Our forests must be managed and protected in such a way that they will never become depleted. Most forests reproduce themselves by natural means after logging. Securing a new growth of natural species is usually a matter of proper management. There are areas, however, from which all possible sources of seed supply have been removed and the existing young growth

Fig. 19-33. Selective cutting in a managed forest such as this means more revenue and perfect specimens of trees.

destroyed by fire. Here forests can only be re-established by seeding and planting.

Several provinces maintain large forest nurseries where stock is grown both for forest planting and for the use of farmers. The output of these stations runs into millions of trees annually.

Our forests belong not only to this generation but to those who will come after us. Therefore, it is our duty to protect and multiply our forest stands, to develop tree crops, to multiply timber harvests, to control the flow of vital waters, and to check soil erosion. Only in this way can we conserve this valuable heritage, so that future generations may benefit from the resources, and enjoy the privileges which are ours today.

REVIEW QUESTIONS

1. What two distinctive forest regions are found within the prairie provinces? **2.** What kind of tree is used more than any other for lumber manufacture? **3.** Describe the characteristics of the forests of the northern transition zone. **4.** What are the most important trees found within the mixed forest belt? **5.** What three valuable species of coniferous trees, not common elsewhere in the prairie provinces, grow in the subalpine forest region? **6.** What products of commercial importance are produced from forest trees? **7.** In what other ways are forests of value to us? **8.** Discuss the reasons for fire damage to forests. **9.** How may these losses be lessened? **10.** What means are now being put into practice in order to control forest fires? **11.** What steps are being taken in order to assure that our forest assets will not be depleted?

QUESTIONS FOR REVIEW AND DISCUSSION

1. What is the purpose of inoculating alfalfa seed? How is this done?
2. What is oil-cake? What is it used for?
3. Distinguish between bread wheats and durum wheat.
4. What precautions must be taken in harvesting alfalfa?
5. Why does Crested Wheat Grass grow well in the prairie region?
6. How are weeds grouped for the purposes of control?
7. What is meant by vegetative propagation?
8. Other than by seeds, how do the following plants reproduce themselves: Couch Grass, Canada Thistle, strawberry?
9. Explain how grain is swathed. When is swathing necessary?
10. Explain why Thatcher and Selkirk wheat were developed.

11. Describe three uses for fall rye.

12. Name three weeds that are resistant to 2,4-D.

13. Why is M.C.P. sometimes used as an herbicide instead of 2,4-D?

14. "Plants of at least two varieties of the same kind of fruit are necessary for fruitfulness." Why?

15. What is a fruit zonation map?

16. How are fruit trees commonly propagated?

17. How is a plum × sandcherry hybrid developed?

18. How should strawberries be protected during the winter?

19. Explain what is meant by root grafting.

20. Distinguish between whip-and-tongue grafting and cleft grafting.

21. If an Assiniboine Plum is grafted on a Pembina Plum, what type of plum will result from the graft?

22. Name two types of deciduous trees that may be used for lumber.

23. Describe the location of the commercial forest area in the prairie provinces.

24. State three reasons why it is necessary to conserve our forests.

25. What measures are being taken to prevent and control forest fires?

26. What is pulpwood? For what is it used?

27. What types of trees grow in the subalpine forest area?

SPECIAL REPORTS AND PROBLEMS

1. How new plants are produced.

2. The work of Burbank, Seager Wheeler, Saunders.

3. How forests prevent soil erosion.

4. Report on a satisfactory method to preserve, mount, and name plant species.

5. The commercial uses of trees.

6. Report on a visit to a sugar-beet refinery.

7. How legumes improve the soil.

8. Report on the comparative values of Crested Wheat Grass, Slender Wheat Grass, and Brome Grass, as hay and pasture crops.

TESTING THE PURPOSES OF THIS UNIT

1. Define or give the meaning of each of the following words or terms: silage, Durum wheat, legumes, seed inoculation, lindane, shelter-belt, annual, winter annual, biennial, perennial, cleaning crop, bulb, runner, rootstock, horizontal root, smoke jumper, leaf mold, coniferous trees.
2. Discuss the advantages and disadvantages of harvesting grain-by (1) a combine, (2) a swather, (3) a binder.
3. Which weeds in the following list are perennials: Blue Bur, Gumweed, Canada Thistle, Field Bindweed, Stinkweed, Leafy Spurge, Tumbling Mustard, Goats-beard, Wild Oats, Toadflax.
4. What kind of fruit is each of the following: Opata, Dolgo, Chief, Perfection, Climax, Gem, Heyer No. 12?
5. What is the difference between root grafting and top grafting?
6. What are the commercial uses of trees?
7. Distinguish between spring wheat and winter wheat.
8. State the specific purpose for which each of the following wheats were developed: Thatcher, Rescue, Selkirk.
9. What cultural methods are recommended for the destruction of Wild Oats?
10. Explain what is meant by selective cutting of forest trees.

The old

THE WORK ON PLANT IMPROVEMENT IS ONE OF THE MOST interesting phases of plant science. Scientists have been able to produce a great variety of food and forage plants, flowers, shrubs, and fruits, suited to varying conditions of soil and climate.

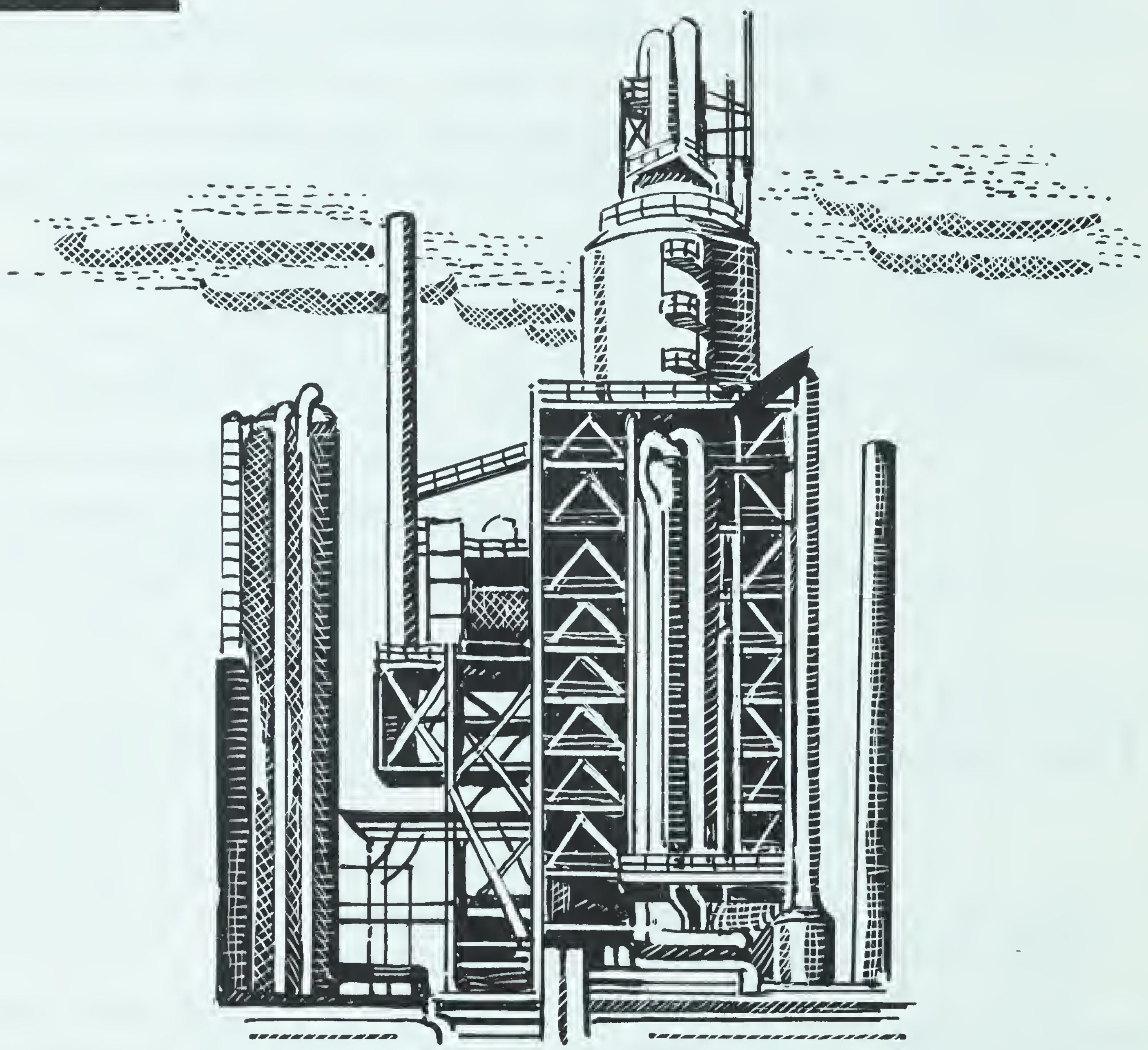
The pioneer plant breeder was Luther Burbank. He carried on his famous experiments over seventy-five years ago in California. Burbank achieved his results by using scientific *crossing* and *selection*. The former process is cross-fertilization of two plants to produce a third. Selection means the choosing of the best, rejecting the unfit. Thousands of plants must be grown in an effort to produce one improved variety and all of these must be examined with extreme care.

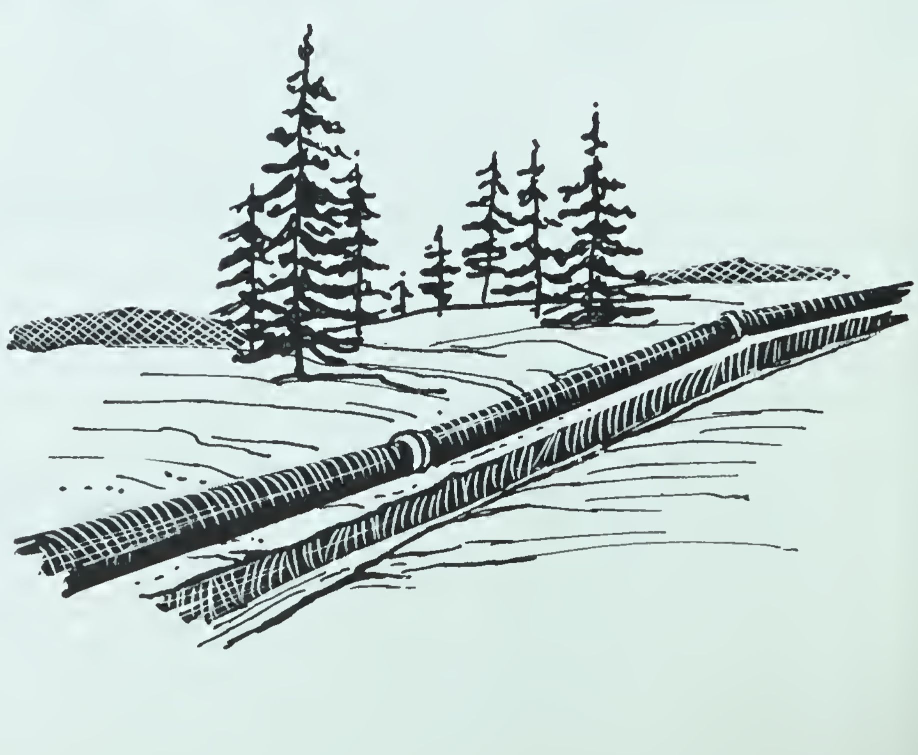
One of Burbank's most interesting creations was the *plumcot*, a pitless plum, resulting from a cross of a Japanese plum with an apricot. Burbank also had great success with his flower experiments. He developed the now well-known *Shasta daisy*, named after his favorite snow-capped peak in the Sierras. This lovely flower, with its brilliant white petals and golden center, grows from two to four inches in diameter.

The new

SINCE BURBANK'S TIME, MAN HAS CONTINUED TO IMPROVE plants. Much of the work is done by trained scientists, but gardeners, seed-growers, and others, have contributed to the progress that has been made. Our best varieties of apples, pears, wheat, oats, and grasses, have been developed after many years of crossing and selection.

Apple seed, if planted in the proper soil, will grow and produce apples but the fruit will not be the same kind as that from which the seed was taken, and may be inferior. To propagate good varieties of apples, man has learned the value of *grafting*. The plants to be grafted upon may be raised from seed, but the buds to be grafted are taken from a tree that is known to produce excellent fruit of the variety desired.



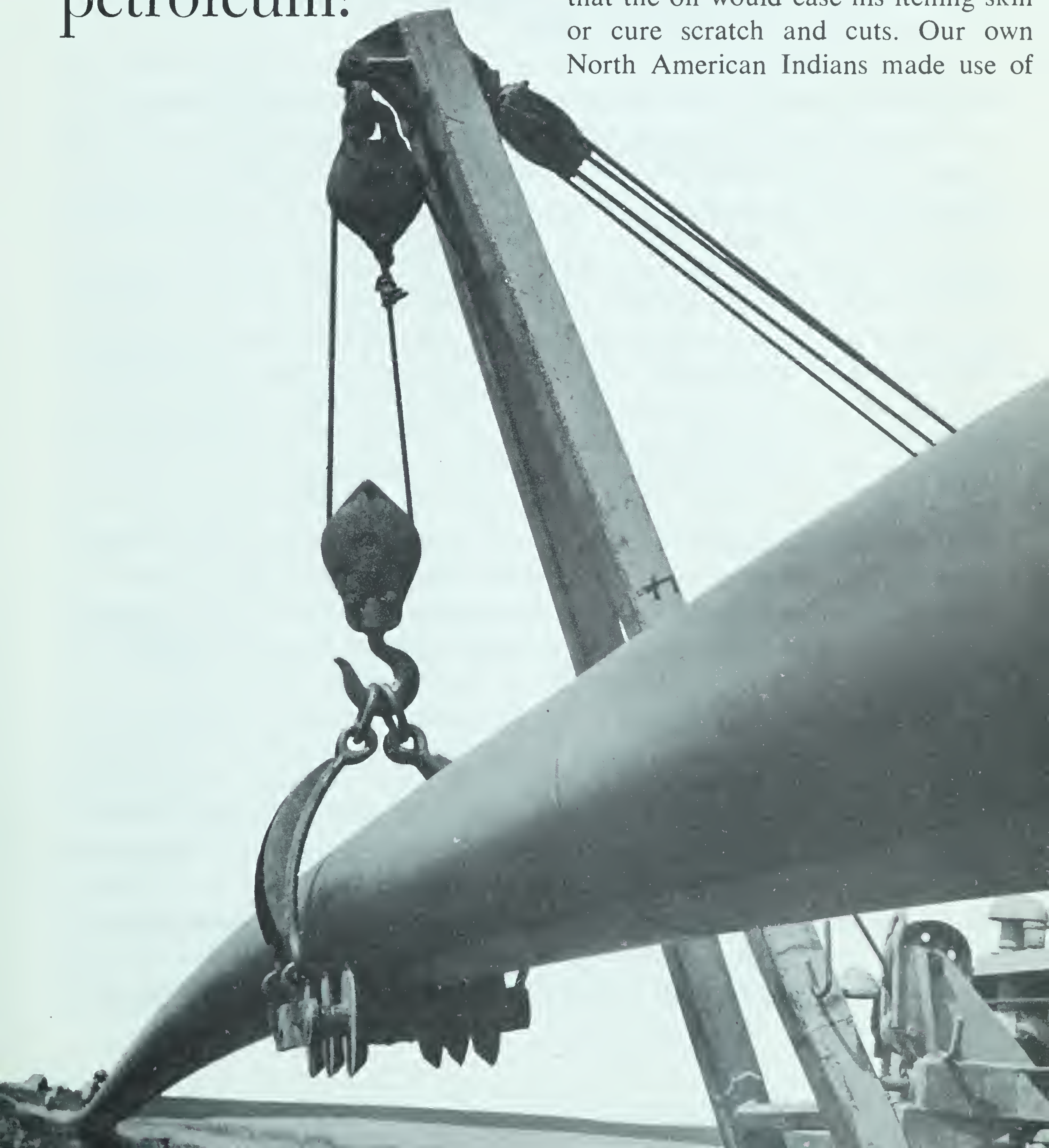


UNIT 20

DISCOVERY AND PROGRESS

How has man learned to find and use petroleum?

EARLY man knew of the existence of oil. As we shall learn later, oil is formed under the earth. Occasionally some escapes and makes its way to the surface where it forms small pools, known as oil seeps. Early man may have bathed himself in seeps, hoping that the oil would ease his itching skin or cure scratch and cuts. Our own North American Indians made use of

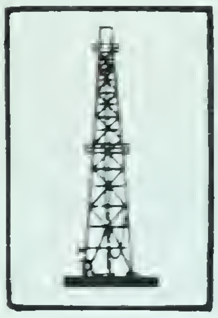


seeps in several ways. They may have drunk the oil as a cure for internal ills. Certainly they used it to grease their skins and to make war paint. A kind of oil, obtained from tar pits, was useful to waterproof canoes.

Early man was not aware that oil from the seeps could be used to heat or light his dwelling. He had discovered, however, that he could make an oil for these purposes by pounding the fat from animals. He made a shallow tray out of soft stone, filled it with animal oil, and floated in the oil a wick of vegetable fibre. As he became a better craftsman he replaced the tray by a pot made from clay, with a spout for the wick. He learned that oil from seal or whale blubber provided the best light and heat. Still later he made his lamps from metal. Over the years he found ways to refine the whale oil which was his best source of heat and light, and he discovered that a glass chimney over the wick made a lamp throw better light.

Until a hundred years ago whale oil was still used as a fuel for lamps. By that time the sperm whale, however, whose blubber provided the best oil, had become almost extinct and others had been driven far away from inhabited shores. It became more and more difficult to get whale oil, and men began to look for other sources of light and heat. A Scotsman, James Young, succeeded in distilling from coal a kind of oil that could be used in a lamp. In Nova Scotia, a little later, Abraham Gesner repeated Young's process but found that he could get better oil by distilling a kind of asphalt. A search began on the North American continent for tar beds. Two were found in southwestern Ontario which appeared to be of asphalt. They were, however, caused by seepage of oil from underground. A man named Williams, from Hamilton, Ontario, who was acquainted with the work of James Young in Scotland, and who had had some experience in distilling oil from seepages in Europe, investigated the area and in 1857 built a small refinery in the woods close to the beds. He dug a well with a mouth four feet square, the same method he would have used if he had been digging for water. Between forty and sixty feet from the surface he found gravel in which there was heavy oil that could be brought to the surface by pumping. This was the first oil well found in Canada. The following year an oil well was drilled for the first time in the United States.

The efforts of the early oil men were directed towards procuring oil for lamps. Such oil was called kerosene, and gasoline, which was also secured from oil by refining, was customarily thrown away as useless. The increased use of electricity as a means of illumination made kerosene lamps out of date. The oil industry might have ended then had it not been discovered that gasoline made an excellent fuel for internal combustion engines. This kind of engine is used in automobiles. The demand for more and better gasoline for cars, and later for trucks, tractors and airplanes, has led to more and more oil production and has brought to Canada a new and important source of wealth.



QUESTIONS TO DIRECT THE STUDY OF THIS UNIT

1. What is crude oil? **2.** What do all crude oils have in common? **3.** How was oil formed? **4.** Where is it found? **5.** What sciences are used in the search for oil, and what are the contributions of each? **6.** How is an oil well drilled? **7.** What natural forces cause an oil well to flow? **8.** What methods are employed in the conservation of gas and oil? **9.** What are the difficulties of transporting oil and how are they overcome? **10.** How are hydrocarbon compounds separated into different petroleum products?

WORDS TO HELP YOU UNDERSTAND THIS UNIT

anticline . . . . . the crest of an arch of rock folded upwards by an upheaval of the earth.

derrick . . . . . . the tower-like structure which supports the tools for drilling a well.

distillation . . . . the process by which a liquid is converted to a vapor then back to a liquid.

fractionating . . the process by which the hydrocarbon compounds contained in crude oil are separated into different parts or fractions.

fault . . . . a rock formation where a porous layer of rocks lies side by side with a non-porous layer.

geology . . . . . . the science of the structure of the earth.

geophones . . . . sensitive detectors which pick up sound waves reflected from rock layers.

hydrocarbon . . a compound of the elements hydrogen and carbon.

outcrop . . . . . . the exposed section of a layer of rock.

palaeontology . (pay-lay-on-*tol*-uh-jee) the science which studies fossils.

petroleum . . . . another name for crude oil.

seismic . . . . . . (*size*-mik) having to do with earthquakes.

seismograph . . (*size*-moe-graf) an instrument for recording the strength of earthquakes.

strata . . . . (singular: stratum) layers of sedimentary rock.

A What is petroleum?

The word "petroleum" comes from two Greek words meaning "rock oil." Later we shall learn why oil has this name. Sometimes it is called mineral oil to distinguish it from animal oils like whale or castor oils, or from vegetable oils like olive and linseed oils.

In appearance and nature, ***crude oil*** varies greatly from field to field. In some fields it is lighter than water and flows very readily. In others it is heavy and thick. In exceptional cases crude oils resemble water in color. Ordinarily they are amber, green, or black.

Though crude oils may vary in appearance and color, they are all alike in one respect. Every crude oil is a complex mixture of the chemical elements, hydrogen and carbon. These are called ***hydrocarbon*** compounds. There are thousands of hydrocarbons present in different combinations in crude oil. One compound of hydrogen and carbon may result in methane or natural gas. Another produces pentane, an important ingredient of gasoline. Pentane is a liquid. Most hydrocarbons are liquid at ordinary temperatures but some are gases and some solids. Crude oils consist mostly of liquid hydrocarbons but they also contain some dissolved solids and gases. We shall learn more about the hydrocarbon compounds later.

REVIEW QUESTIONS

1. What does the word "petroleum" mean? **2.** In what respect are all crude oils alike? In what ways do they differ? **3.** What name is given to the chemical compounds of which crude oil is composed? Why? **4.** In what forms are these compounds found?

B How was oil formed?

No one knows, exactly, how crude oil was formed. Most scientists believe that it was produced many centuries ago under the ocean. Then, as now, the oceans were the home of marine animals and plants such as fish and seaweed. In addition, their waters teemed with billions and billions of very small animals and plants. As these died their bodies sank to the bed of the ocean where they were covered by mud, sand and lime.

Into the oceans ran rivers and streams whose waters carried down with them the carcasses and bones of animals that had died on their banks. They brought other things, too: dead leaves, twigs, branches of trees, and vast quantities of sand and other sediments. The ***sediments*** were formed by the constant action of wind, water, frost and other natural forces on the earth's surface. Washed down to the sea, the sediments were piled high over the animal and plant remains. This process continued for millions of years till the piles of sand and sediment were some-

times thousands of feet in thickness.

In time the great pressure of the upper layers of sand and sediment on the bottom layers squeezed the water out of them and made them into solid rocks. The task of making sand into rocks was aided by two other agents: pressure from below when the ocean floor periodically heaved up, and heat from the interior of the earth.

Rocks formed from sediment in this manner are known as sedimentary rocks. Since different kinds of sediment were deposited at different times, the layers, or ***strata***, of which sedimentary rocks are composed will vary. Some of these strata are porous, that is, full of pores which permit liquids and gases to pass through them. Others are nonporous and will not permit the passage of gases and liquids. The most common kinds of porous rock are limestone and sandstone.

While these changes were taking place in the sediment, an equally important change was occurring in the animal and plant remains that had been buried in the sediments on the ocean floor or between the strata. These had gone through a process of chemical decomposition which, aided by the action of bacteria, by pressure, and by heat from the earth's interior, had turned them into the compounds of hydrogen and carbon which are known as petroleum.

As water was forced by pressure out of the mud and slime which were being pressed into rocks, it carried the crude oil and gas with it. These made their way into the pores of the porous rocks. That is why crude oil is also called ***petroleum***, or rock oil.

ANTICLINE

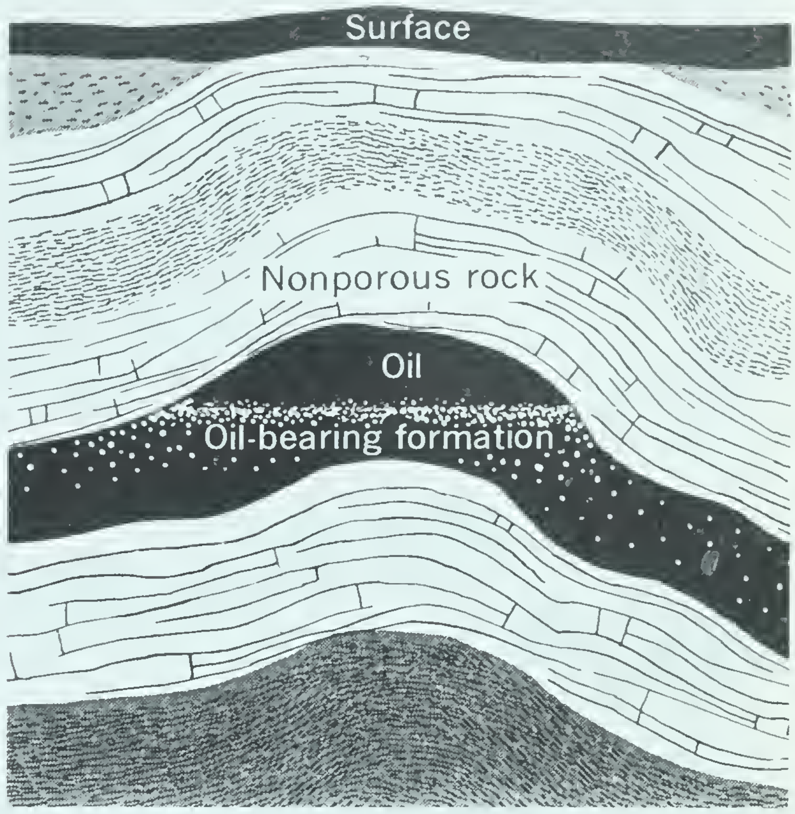


Fig. 20-1. This diagram shows one earth formation, the anticline, in which oil is commonly trapped. Oil is usually found in association with natural gas and salt water.

REVIEW QUESTIONS

1. Where was crude oil formed? **2.** From what was it formed? **3.** What were the forces that combined to form crude oil? **4.** What are sedimentary rocks and how do they differ from one another?

C Where is oil found?

Crude oil is found today concentrated in porous rocks. The oil, gas and salt water travelled through the layers of porous rock sometimes for great distances. Eventually, however, they reached a point where they could travel no farther. Their way was obstructed by non-porous rock. Unable to move

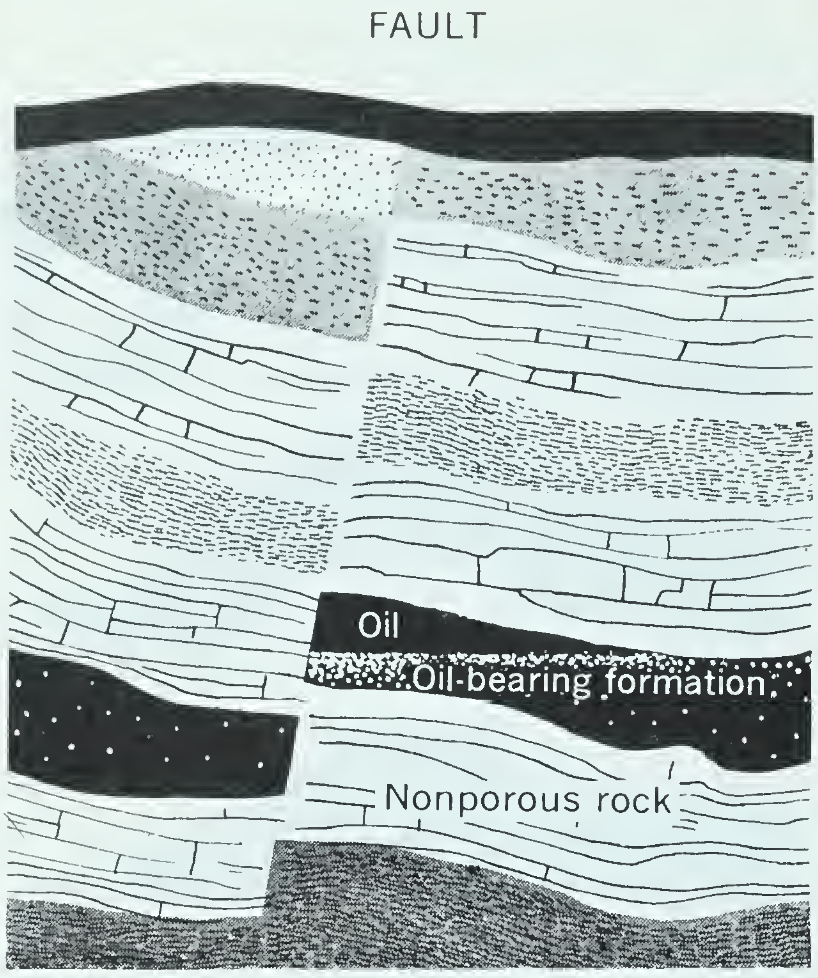


Fig. 20-2. A fault in the earth's structure is the second most common type of oil-trap. How were such faults formed?

in any direction, the oil and gas formed a pool at this point.

The word "pool" conjures up a picture of a body of liquid like a slough or lake. An oil pool, however, is not a large underground space filled only with crude oil. It consists, instead, of a large area of porous rock or sand whose pores are filled with crude oil and which is overlaid by non-porous rock. Oil men usually call an oil pool a reservoir.

The layers of sedimentary rock, when they were first formed under the ocean, were almost horizontal. But the floor of the ocean was subject to periods of violent upheavals. These upheavals folded the rocks into a series of irregular arches and depressions. The crest of an arch formed in this way is called an ***anticline***. Crude oil was often trapped in the top of anticlines. Natural gas is frequently found in the same anticline as crude oil. When this occurs, the gas occupies the space in the porous rock above the crude oil. Usually salt water is found in the space below the oil.

A second kind of trap in which crude oil was caught is known as a ***fault***. During the periods of violent upheaval of the earth's surface, some rock strata were cracked and pushed past one another so that a layer of non-porous rock might be found opposite a porous layer. Such a structure is called a fault and crude oil was sometimes collected in faults.

If oil was formed under the surface of the ocean, why is it found today in enormous quantities beneath land masses like the Canadian prairies which lie many hundreds of miles from any ocean? The answer is to be found in the upheavals of the earth's surface. The western prairies must at one time have lain under an ocean. Throughout the centuries, however, great earth movements changed the position of the ocean and threw up earth masses to form the continents and islands as we know them today. For this reason the oil and natural gas first formed beneath an ocean now lie in the rocks under the western prairies.

We should know now the kind of area in which crude oil is likely to be found. Beneath its surface, there should be beds of porous rock, preferably sandstone or limestone. These rocks should have sufficient pore space to hold a large volume of oil. They should be sealed off by non-porous rocks in formations such as anticlines and faults

Fig. 20-3. A field geologist, in his tent at the end of the day's exploration, draws and colors the formations he has investigated during the day. What information should the finished map give the oil explorer?

which form reservoirs in which the oil and natural gas are trapped. It is areas with these characteristics that the oil men explore in their search for new oil wells.

REVIEW QUESTIONS

1. In what kind of sedimentary rock is oil found? **2.** What is an oil pool? **3.** What are the two most common forms of oil trap? **4.** How was each formed? **5.** In what kind of an area is crude oil likely to be found?

D What are the first steps in the search for oil?

When an oil company decides to explore a certain area where oil may be found, it sends out first a crew of geologists. *Geology* is the science that investigates the structure of the earth, and geologists are men trained to read the story of the formation of the earth in its rocks and strata and their relation

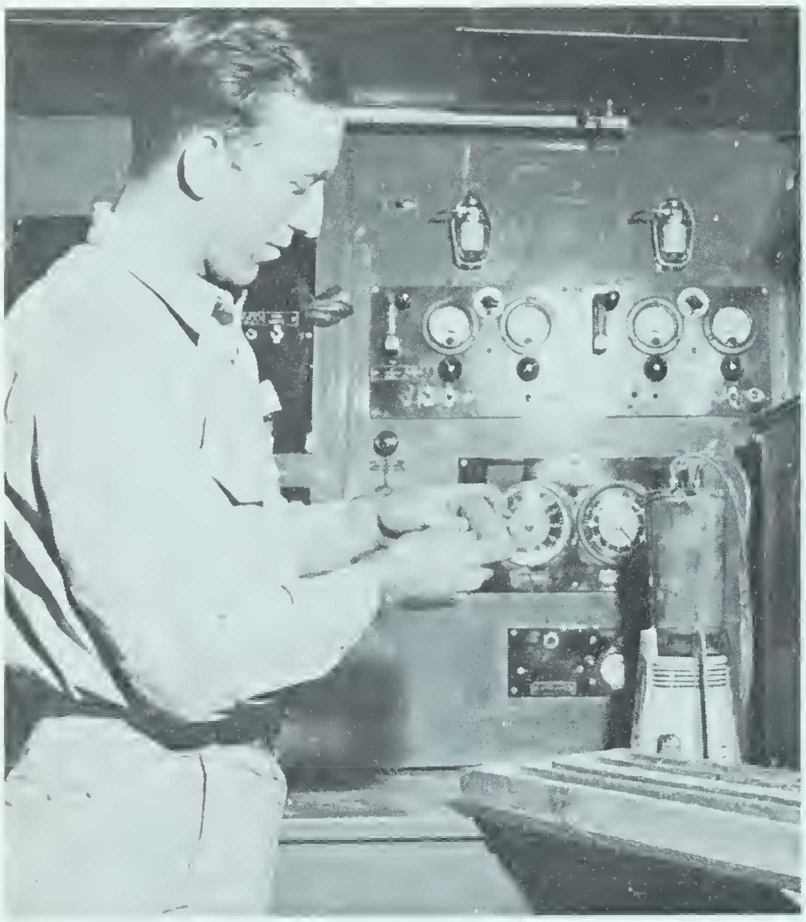


Fig. 20-4. Another scientist, the palaeontologist, examines a core of rock brought to the surface by a portable drill, for traces of the presence of certain types of marine fossils.

to one another. The task of the geologist is to find districts where the rock structures are of a kind in which oil in large pools might be found. The geologist first observes any exposed rocks in the area and takes samples of them for closer study. He measures the direction in which the exposed rocks, or ***outcrops***, appear to slope. He also consults any records, that are available in the district, concerning the digging of water wells, mine shafts, or old oil wells.

In some areas in western Canada where oil has been found in commercial quantities, there are few or no outcrops for the geologist to observe. He then makes use of a small portable drill, called a core drill, to help him in his explorations. With this he obtains cores or samples of rock from different depths at a number of points beneath the surface. The cores are sent to a laboratory where they are examined under a microscope and subjected to chemical treatment. From their study of the cores, the geologists learn what kinds of rock are to be met at different depths. They also compare the cores with those obtained from other formations known to exist in the same area. After this research, the geologist is able to draw a map of the kinds of rock which lie immediately below the surface. From this he tries to determine if their pattern of rock strata will be repeated in successive layers to a greater depth.

Sometimes cores are sent to another kind of scientist, the ***palaeontologist***. The palaeontologist is trained to identify fossils, the remains of prehistoric animals or plants, which are often found imbedded in rocks. If the palaeontologist discovers in a rock core the fossils of certain types of small marine animals and plants, it is one more indication that oil *might* be present in the area.

Core drilling cannot be carried to very great depths. Other scientists are brought in to help identify the rock strata lying farther below the surface in the area being explored. One of these is the ***geophysicist***, a man who brings a knowledge of physics to the study of the earth's formations. If the report of the geologists is a favorable one, indicating that further exploration is warranted, a ***seismic*** crew is sent into the area. "Seismic" is a word which means "having to do with an earthquake," and the task of the seismic

crew is to produce a series of small earthquakes. The crew travels a line several miles in length, along which, at intervals about a quarter of a mile apart, holes up to a hundred feet are drilled. In the bottom of each hole a charge of dynamite is placed and exploded. Sound waves set in motion by the explosion pass readily through certain kinds of rock but from others, particularly limestone, they are reflected back to the surface. Here they are picked up by sensitive detectors called ***geophones***, and recorded in a series of squiggly lines by a ***seismograph***. The seismograph can measure, to the one-thousandth part of a second, the time which passes between setting off the charge and receiving the returning sound wave. From these measurements it is possible to determine fairly accurately the kind of rock which lies far below the surface and the depths of the strata from which the sound was reflected. This information enables

Fig. 20-5. This photograph shows a seismic crew at work. A seismograph in the truck in the foreground records the shock waves created by the explosion.

Fig. 20-6. The waves recorded by the seismograph appear as long squiggly lines on a strip of photographic paper called a seismogram.

another map to be made showing the shapes of the strata likely to be encountered at lower depths.

These are some methods by which science helps the oil men in their search for oil. There are others which we shall not deal with here. You will have noticed that none of these methods actually detects the presence of oil. The best that the geologist, the geophysicist and the palaeontologist can do is to report that in the area which has been explored certain rock structures exist which show promise of containing oil, or are similar in nature to structures in other districts where oil was found. But oil, as the oil men say, is where you find it, and the final proof of the presence or absence of oil can be obtained only by drilling for it.

REVIEW QUESTIONS

1. What is geology? **2.** What parts do the geologist and the palaeontologist play

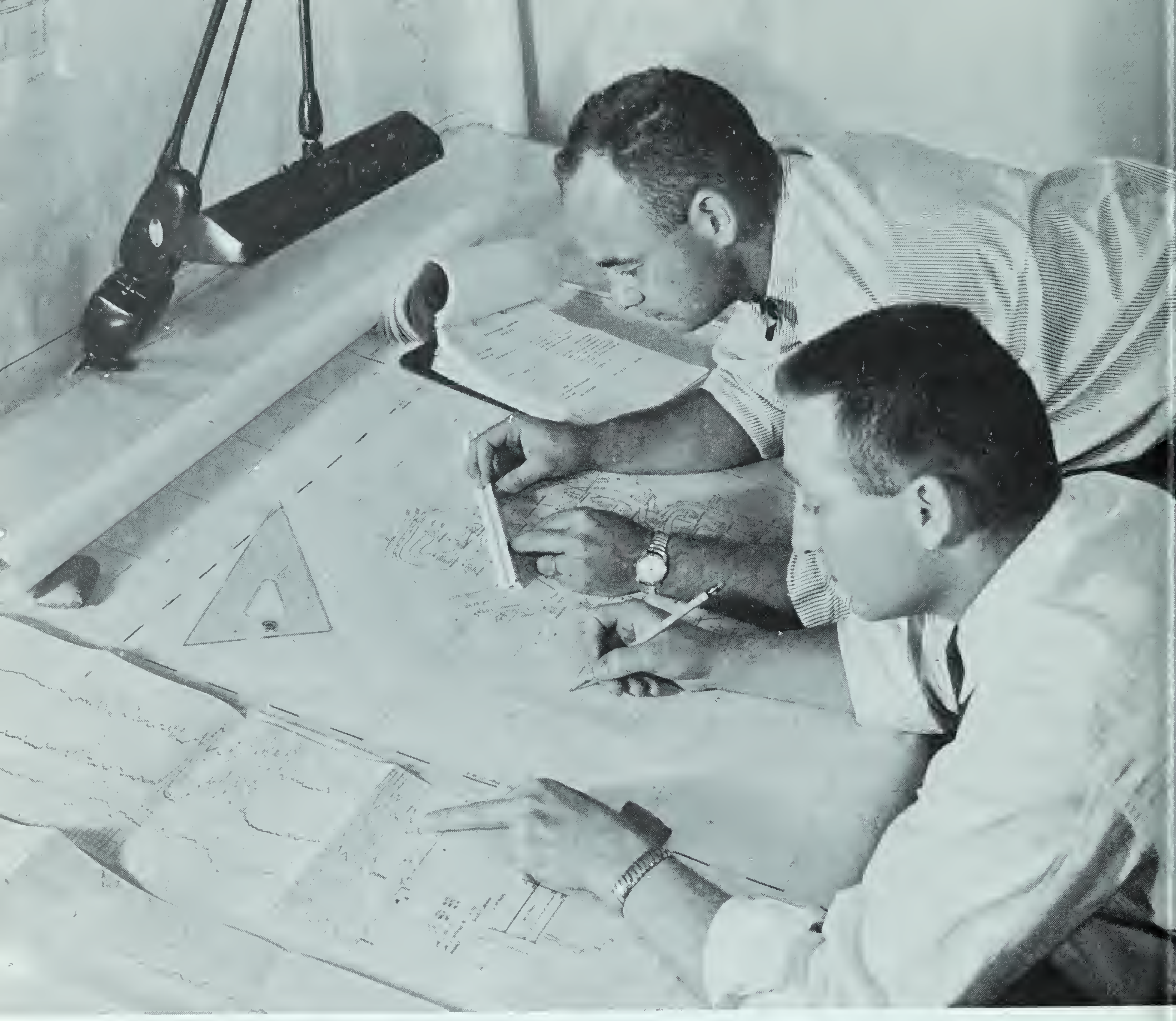


Fig. 20-7. Calculations from the seismogram help these men to map the rock formations which lie deep below the surface of the area being explored.

in the search for oil? **3.** What research must a geologist carry out before he can draw a map of the area under investigation? **4.** What will his map show? **5.** What are the tasks of a seismic crew? **6.** What equipment does the seismic crew use?

E How is oil found?

Driving an oil well into a new area where no other wells are in operation is known as wildcatting. To drill an oil well is a very expensive project. In Canada it is made even more expensive by the fact that only about one out of every seventy-five holes dug in territory where no oil has previously been found will produce oil in commercial quantities, that is in sufficient quantities to make it worth operating. A commercial field should yield at least a million barrels of oil. The other seventy-four are known as dry holes. Sometimes the odds against finding oil in a given area are even greater. In 1947 a Canadian company was prospecting for oil near Leduc, Alberta, about twenty miles

south-west of Edmonton. The company had previously drilled 133 wells in the area, producing nothing but dry holes. The 134th well brought oil in commercial quantities and uncovered a vast new oil field. The company, however, had spent many millions of dollars in prospecting and drilling the area before Leduc No. 1 was brought in.

When it is decided to drill at a certain spot, a great tower called a ***derrick*** is first erected there. In the early days of oil drilling the derrick was built of wood and remained over the well when it was brought into production. Modern derricks are made of steel and are towed in sections on trucks from place to place. When erected, they stand about 140 feet high.

When Williams discovered Canada's first oil well he dug it in the same way that he would have dug a water well. Williams, however, found oil at between forty and sixty-five feet. Modern wells are much deeper. Some have been only a few hundred feet deep, others have been drilled to a depth of more than two miles. The deepest well in Canada to date is 14,686 feet. No oil was found in it. On the average the drill must go down about 3,000 feet before oil is reached. Better and safer methods than Williams' have had to be devised in drilling for oil at such depths.

There are two methods in use today. The first is called cable tool drilling. In this a heavy steel implement called a bit is alternately raised and dropped by equipment at the top of the derrick, thus pounding its way through

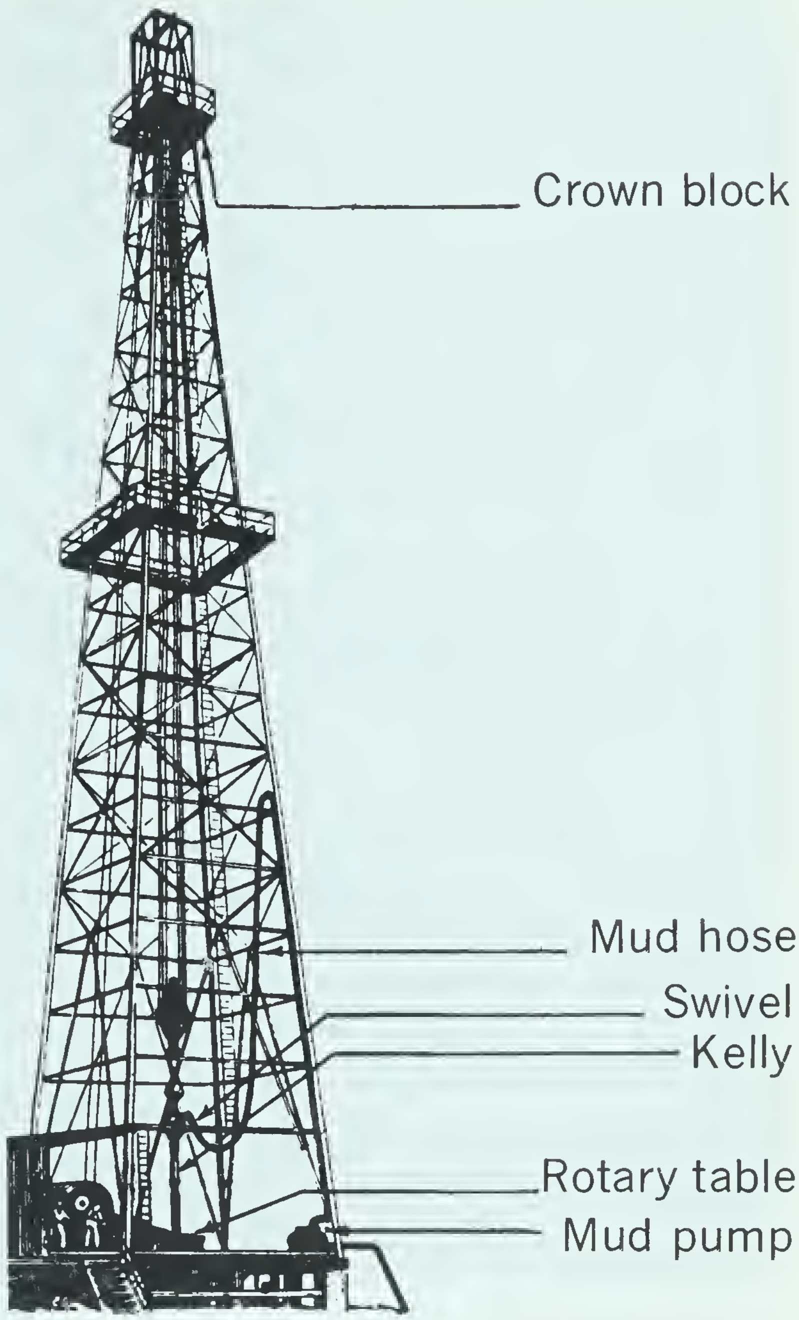


Fig. 20-8. This diagram shows the parts of a drilling rig.

the rock and clay it strikes. Cable tool drilling is used to some extent in drilling shallow wells,. but it is slow compared with rotary drilling, the method most commonly used in the exploration areas of western Canada. In rotary drilling, the bit, instead of pounding its way into the ground, is rotated on the end of a hollow stem called a drill pipe, and the hole is made by boring.

The bit is short and heavy, and a typical one weighs about 100 pounds. In appearance it resembles a closed fist in which the knuckles are spike-toothed gears. The bit screws on to a device

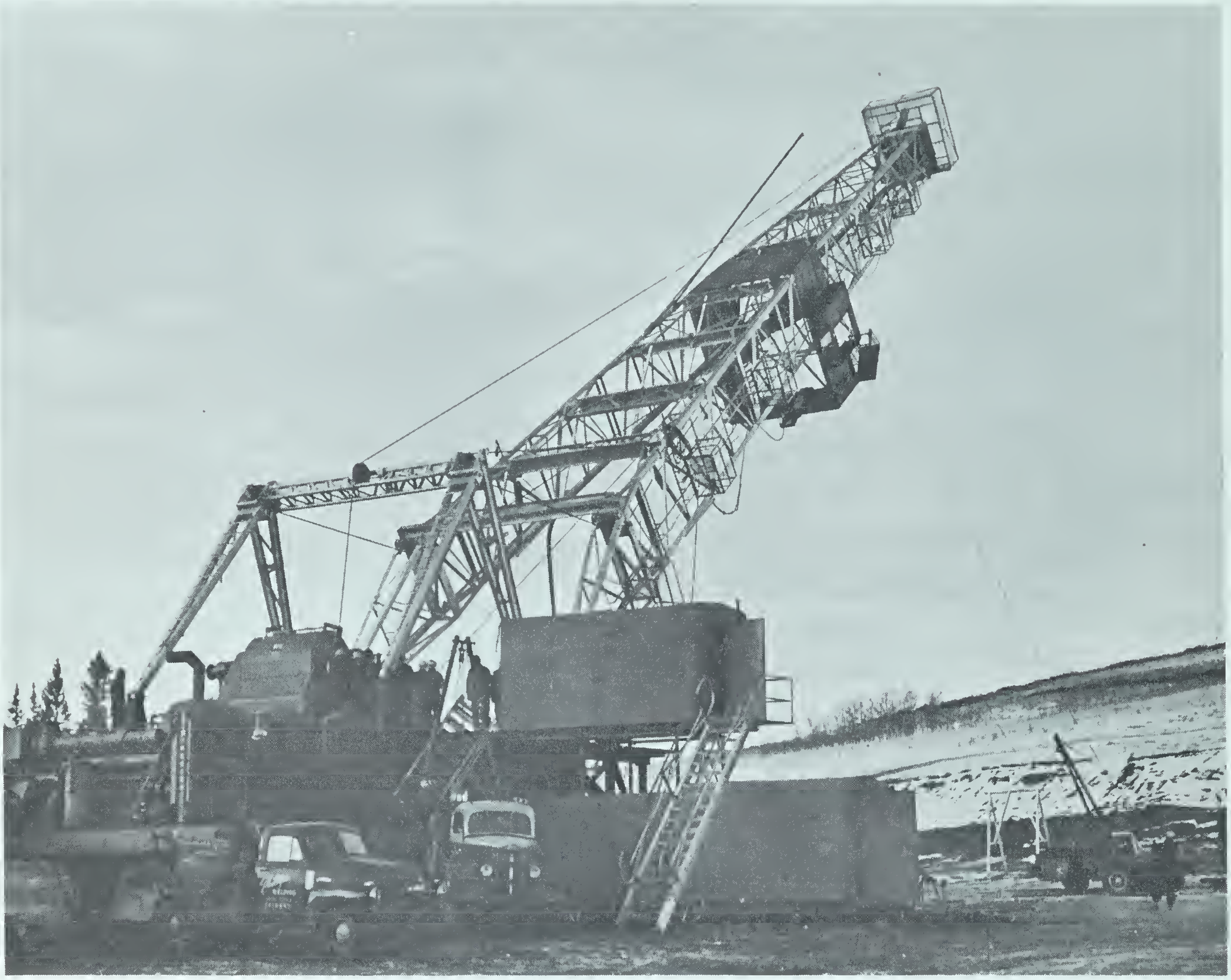


Fig. 20-9. The modern derrick is of steel construction and is hauled from site to site by truck.

called a drill collar, which in turn is screwed to the lower end of a length of drill pipe. Each section of drill pipe is about thirty feet long. The top end of the drill pipe is attached to the bottom of a steel bar called a kelly whose top is fastened to a swivel which is suspended by a cable from the top of the derrick. The kelly, usually square in shape, passes through a hole of the same shape in a turntable called the rotary table. Machinery operated by steam or diesel engines causes the turntable to rotate and with it the kelly, which in turn rotates the drill pipe and the bit.

When all these pieces have been fitted together the bit is lowered to the ground and the drilling begins. Oil men call this "spudding in." As the bit cuts its way into the ground, the cable is paid out, lowering the kelly down through the rotary table. When the top of the kelly is almost level with the rotary table, drilling is stopped. The drill pipe with the bit is raised to permit the kelly to be unscrewed and lifted up to its first position by the cable. A second length of drill pipe is then screwed to the first length and to the kelly and the drilling is resumed. This process is repeated again and

again as the bit drills deeper and deeper into the ground.

Beside the derrick a hollow has been scooped and in this a special kind of mud is mixed. The mud is pumped up from the hole and down the inside of the drill pipe which, as we know, is hollow. It passes out of the pipe through holes in the bit. The mud then rises to the surface again in the space between the drill pipe and the wall of the hole. As it rises it carries with it out of the hole the rock cuttings chipped out by the bit. Samples from these cuttings are studied carefully for evidence of the kind of rock through which the drill is passing. The mud, in rising back to the surface, plasters a cover over the wall of the drill hole. This helps support the wall and keep it from caving in. As the hole grows deeper the support of the mud alone is not enough. The hole is then lined with casing, a heavy steel pipe which is cemented to the wall.

The speed at which a well is drilled depends on the kind of rock formations through which the bit is passing. Under favorable conditions several hundred feet of hole may be made in a day. There are, however, inevitable delays. If the bit is passing through very hard rock, it can be dulled rapidly and must be frequently replaced by a sharp one. From time to time the bit is removed and a special coring bit attached which takes out a cylinder of rock for study in the laboratory. The worst delays, however, are caused when the bit breaks off deep in the earth. When this happens days may be lost in trying to recover it. Sometimes the bit has to be left where it is and the hole drilled around it. Drill operators call these attempts at recovery "fishing expeditions." Drilling a well is such an

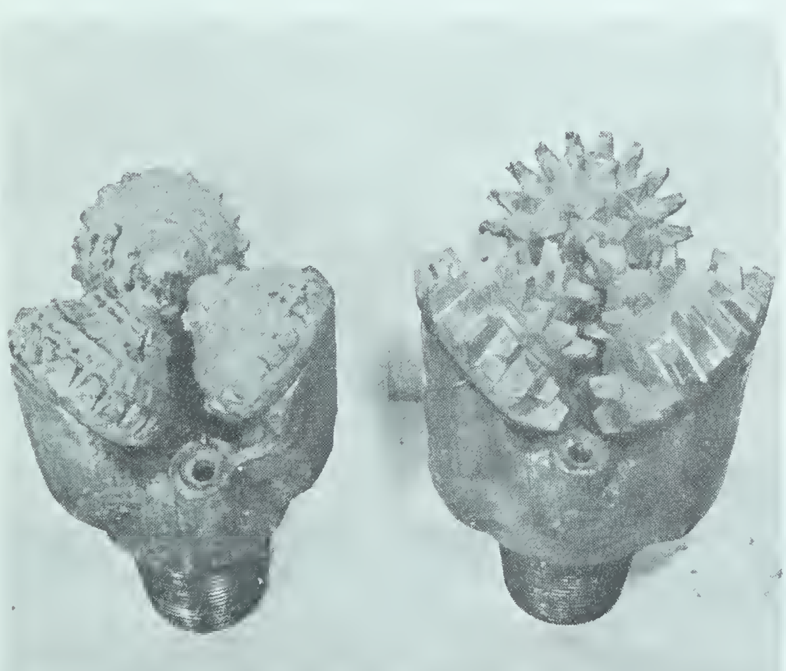


Fig. 20-10. A comparison of the worn bit on the left with the new bit on the right gives a good idea of the kind of formation through which a bit must drill.

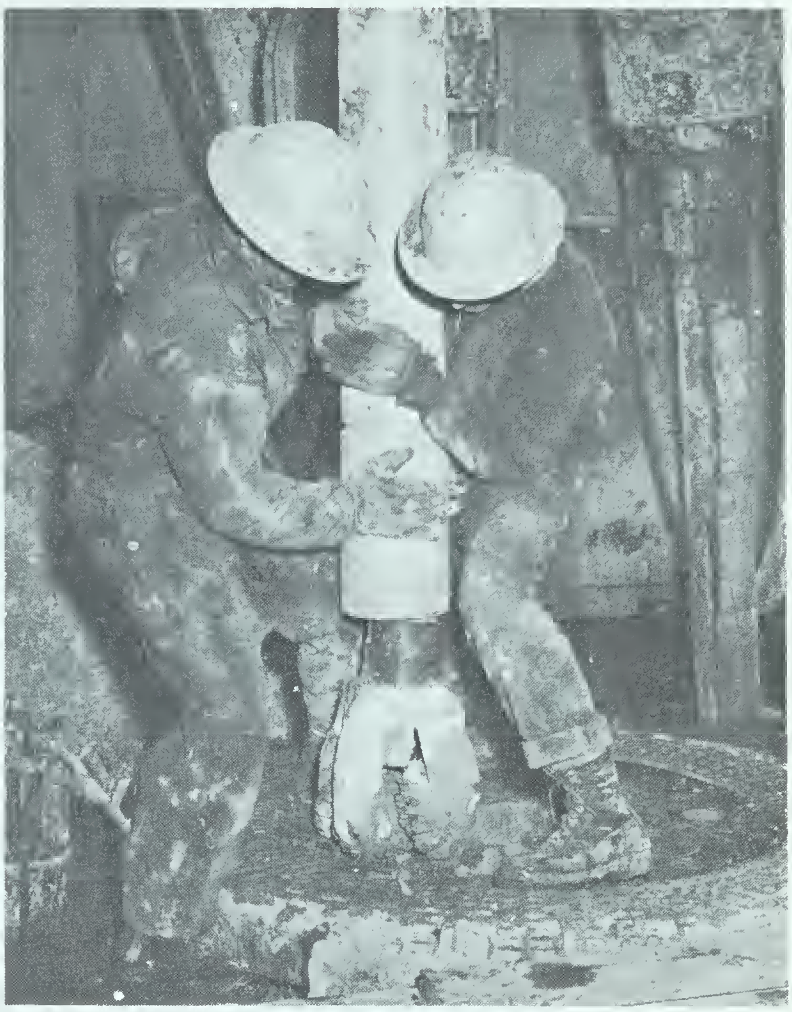


Fig. 20-11. A worn bit is brought to the surface for inspection. Account for the mud on the men, on the bit, and on the rotary table.

expensive business that the drill usually operates twenty-four hours a day with shifts of men relieving one another at regular periods. In this way the costly equipment is not left standing idle at any hour.

REVIEW QUESTIONS

1. What is meant by "wildcatting"? **2.** What percentage of wells drilled will produce oil in commercial quantities? **3.** What purpose does a derrick serve? **4.** How is the process known as cable tool drilling carried out? **5.** In what ways is rotary drilling a superior method? **6.** How does a rotary drill work? **7.** Why is mud used in drilling for oil?

F How is oil brought to the surface?

Usually oil is brought to the surface by natural pressure. You may have seen movies of an oil well being brought in, in which great fountains of oil gushed up in the air higher than the derrick over the well. In the early days of drilling, wells did gush in this manner but it is dangerous and wasteful to permit it to happen.

When an oil pool is reached by the drilling equipment the oil tends to rise in the hole and to flow naturally out of the well. The rise of the oil is caused by underground pressure. In deep wells the pressure can be as much as 10,000 pounds to the square inch. Oil, as we have learned, is usually found with natural gas lying above it and water below it. Gas is lighter than oil, water heavier. Some of the natural gas is also dissolved in the oil, held there by pressure. When the drill bites through into the oil area the mud being pumped down the drill pipe serves as a kind of fluid cork to control the pressure. If the mud is not heavy enough other ingredients are added to make it heavier. If the pressure continues too great the drill-crew quickly shuts off the natural gas area with steel pipe but leaves the hole open in the oil area. The gas under pressure and the heavier water, also under pressure, force the oil out of the porous rock into the well and up to the surface.

Since it is the pressure of water and

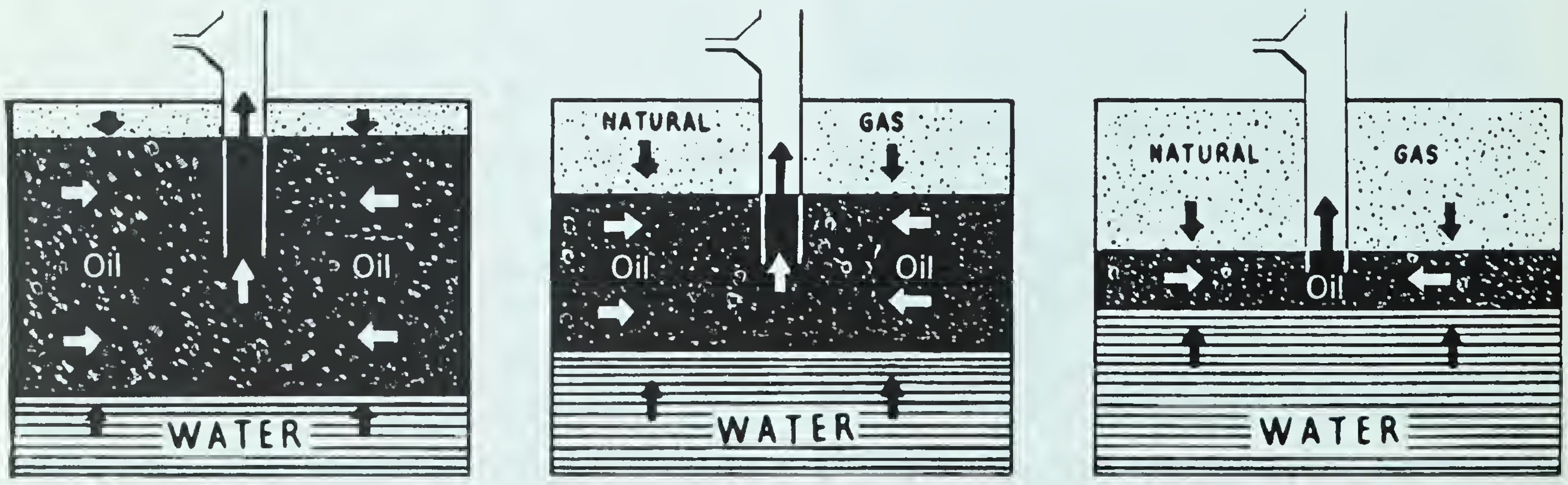


Fig. 20-12. Water and gas both play an important part in bringing oil naturally to the surface.

Fig. 20-13. When crude oil no longer flows naturally from a well it must be pumped.

gas that drives the oil to the surface, it is important that they should not be allowed to escape from the well and their pressure wasted. It is easy for this to happen, since water and gas pass through porous rock more easily than oil and so can move into the well from above and below the oil, before the oil can come in evenly from the sides. When this occurs, the gas in the oil, seeking to escape and no longer confined, gushes into the hole and up to the top, driving the oil upward with tremendous force. It was this which caused the gushers of the old days.

If oil is produced slowly, through a small opening at the top of the well, the water and gas pressure is maintained evenly on the whole layer of oil. The oil flows to the surface through a pipe of smaller dimension, called tubing, which is run down into the well. Then a strange device which the oil men call a *Christmas tree* is fitted to the top of the well. This is a complicated arrangement of pipes and valves which controls the flow of the oil.

Even with such controls, a time comes when natural pressure is not sufficient to force the oil to the surface and mechanical means have to be used. The most common of these are specially designed electric or hydraulic pumps. When these are placed in position over the well they pump oil twenty-four hours a day. There are usually many wells in the same area with a pump over each one. A traveller who drives through a prairie oilfield and watches the great walking beams of the pumps move rhythmically up and down may be pardoned if he thinks that he is observing a herd of mechanical monsters feeding in the grain fields.

Fig. 20-14. This complicated arrangement of valves and pipes, called a "Christmas tree," is used to control the flow of crude oil.

Oil is an important natural resource which must be conserved. Accordingly, most provinces in which oil is found have passed laws limiting the number of barrels of oil that may be taken out of a well each day. The purpose of this legislation is to prevent waste and to make sure that the natural forces that drive oil to the surface are not exhausted by improper production methods. The oil men willingly co-operate in these plans for conservation and have devised means of their own to get the utmost in production from each well. They space their wells far enough apart so that the natural pressure of gas and water will be used most efficiently. When even the pumps are no longer able to bring a sufficient quantity of oil to the surface, the operators of the field may pump water down certain selected wells so that the increased pressure will drive the remaining oil in the area to the unflooded wells. Sometimes, too, dry gas is separated from the crude oil and forced back into certain wells to supply additional pressure. It is not yet possible to recover from an oil pool every drop of oil it contains, but modern conservation methods are succeeding in producing more and more oil from each well drilled.

REVIEW QUESTIONS

1. What force brings crude oil to the surface? **2.** What two other resources are usually found in association with oil? **3.** How do these help bring oil to the surface? **4.** What are gushers and what causes them? **5.** What is a "Christmas tree" and what is its function? **6.** When natural forces are no longer sufficient to bring oil to the surface what mechanical means are used? **7.** What conservation methods are employed in modern oil fields?

G How is oil transported to the refinery?

When oil comes from the ground it contains impurities. These consist of water and sediment from the rocks in which it was stored. As a first step in the production of the many products obtained from oil, impurities must be removed from it. The oil as it comes from the wells moves through flow lines from the Christmas tree to a group of vertical steel cylinders close to the well. These cylinders are called separators. In them natural gas is separated from the oil. Then the oil passes through pipes to field storage tanks where it remains until any water present settles out. The oil can then be moved to the refineries.

Refineries are usually erected near the great centers of population such as Vancouver, Edmonton, Regina, Sarnia, Toronto, Montreal, where the products, refined from the crude oil, will ultimately be used. It is more economical to move the crude oil than to ship to the large cities the many products refined from it. Transporting oil, however, presents several problems. Oil is volatile. It is always trying to evaporate and so it must be enclosed in containers while it is being transported.

Fig. 20-15. The construction of a pipeline is a formidable task. What characteristic of crude oil makes a pipeline the ideal method of transporting it?

Everyone has seen some of the means by which oil is carried to and from the refineries. The early oil men moved the oil about in single barrels and modern oil men still talk of barrels as a unit of measure. The barrel is 35 Imperial gallons. But the single barrel method is slow and new methods have had to be devised. Much crude oil today is transported in great steel barrels mounted horizontally on trucks or railroad cars. A truckload of oil may be as much as 5,000 gallons. An average tank car holds 7,000 gallons.

Today the fastest and most economical method of moving oil is the pipeline. There are two great oil pipelines in Canada and several smaller ones. In 1950 Interprovincial pipeline was laid from Alberta to the head of the Great Lakes at Superior, Wisconsin, from where the oil was transported by tank ships to the refineries. Two years later the pipeline was completed to Sarnia, Ontario. Interprovincial, 1,772 miles in length, is one of the longest crude oil pipelines in the world. In 1953 a second pipeline, Trans-Mountain, was built from Alberta to Vancouver, a distance of 787 miles, to carry western crude oil to the Pacific coast.

Gathering lines from the oil fields deliver the crude oil to the main pipe-

Fig. 20-16. Crude oil is carried by pipeline, boat and train to refineries in every part of Canada. The refinery shown above is at Sarnia, Ontario. What features of the geographic location of Sarnia induced the oil company to locate a refinery there?

lines. The oil is helped in its passage by big pumps installed at different points along the length of the line. Constant watch is kept on the pipelines, usually from a light airplane flying low, whose pilot watches for signs of breaks in the line. The flow of crude oil never stops. Day and night the oil pours through at a rate of two or three miles an hour on its way from the field where it was found to the refineries near the great cities where it will be turned into more than 1,000 separate products.

REVIEW QUESTIONS

1. Why must crude oil be purified? **2.** Where are oil refineries usually built? Why? **3.** What characteristic of oil makes it difficult and dangerous to transport? **4.** How is this difficulty overcome? **5.** What is the most modern method of transporting oil? **6.** Where is this method used in Canada?

H How is oil refined?

When the crude oil arrives at the refineries it is stored until needed in large, round, silvery tanks. The task of the refinery is to separate the crude oil into its different parts. Oil men call these parts fractions. Earlier, it was mentioned that crude oil is composed of many compounds of hydrogen and carbon. These compounds differ from one another in many ways. For the

purposes of refining, however, the most important difference is that each fraction has its own boiling range. Gasoline and kerosene, which are thin and light fractions, have low boiling ranges; asphalt, a thick, heavy fraction, has a very high boiling range.

If water in a kettle is boiled it will turn to steam at 100°C. If the steam is collected and cooled, or condensed, it will turn back to water. The steam will become a liquid at 100°C, the same temperature at which the liquid became a vapor. This process of heating a liquid till it becomes a vapor, then collecting and cooling it, is known as distillation. It is one principle used in refining petroleum.

The process of distilling is carried out in a steel tower about 100 feet high, called a *fractionating* column. It is fitted with a series of perforated steel plates called trays. Close by the fractionating column stands a furnace through which rows of continuous steel pipes are passed. The hydrocarbon compounds in the crude oil, moving through these coils, are turned by the heat into vapor each at its own boiling point and as a vapor pass into the fractionating column. The temperature at the bottom of the tower is very high; it grows less at various points up the tower. As the vapor rises in the tower it passes in turn through the temperature ranges at which each hydrocarbon compound was turned into vapor. In this range the vapor condenses back to a liquid which is drawn off from the appropriate trays by pipes. The heaviest compounds,

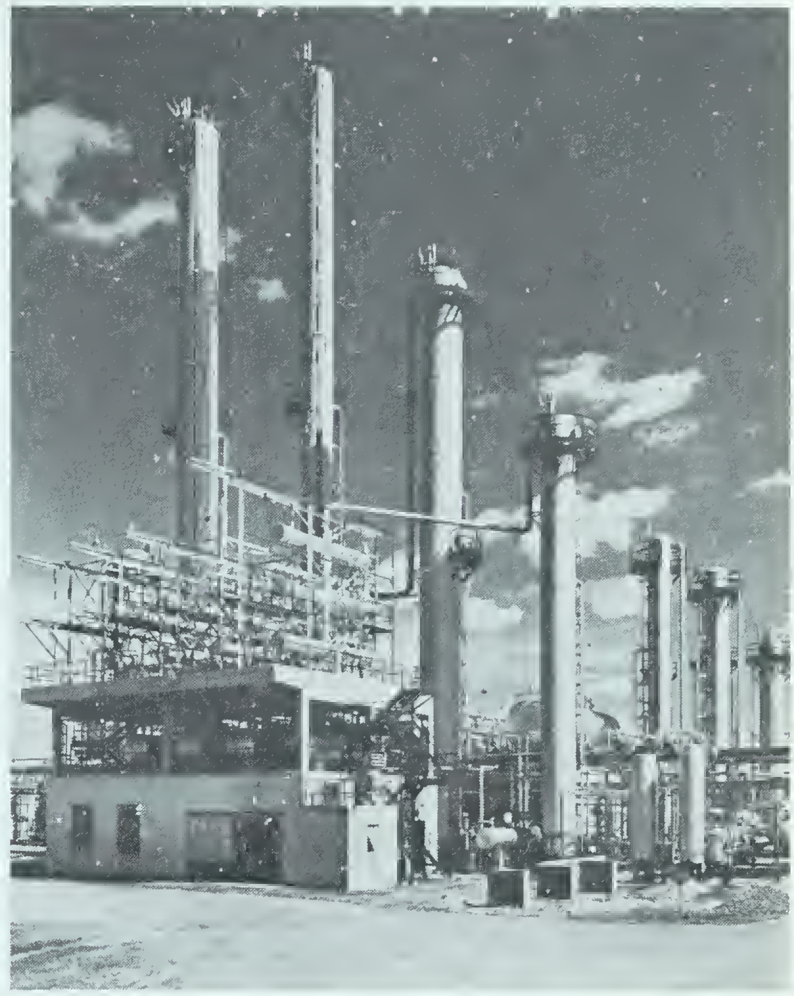


Fig. 20-18. These tall columns are fractionating towers. The building in the foreground is a pump-house.

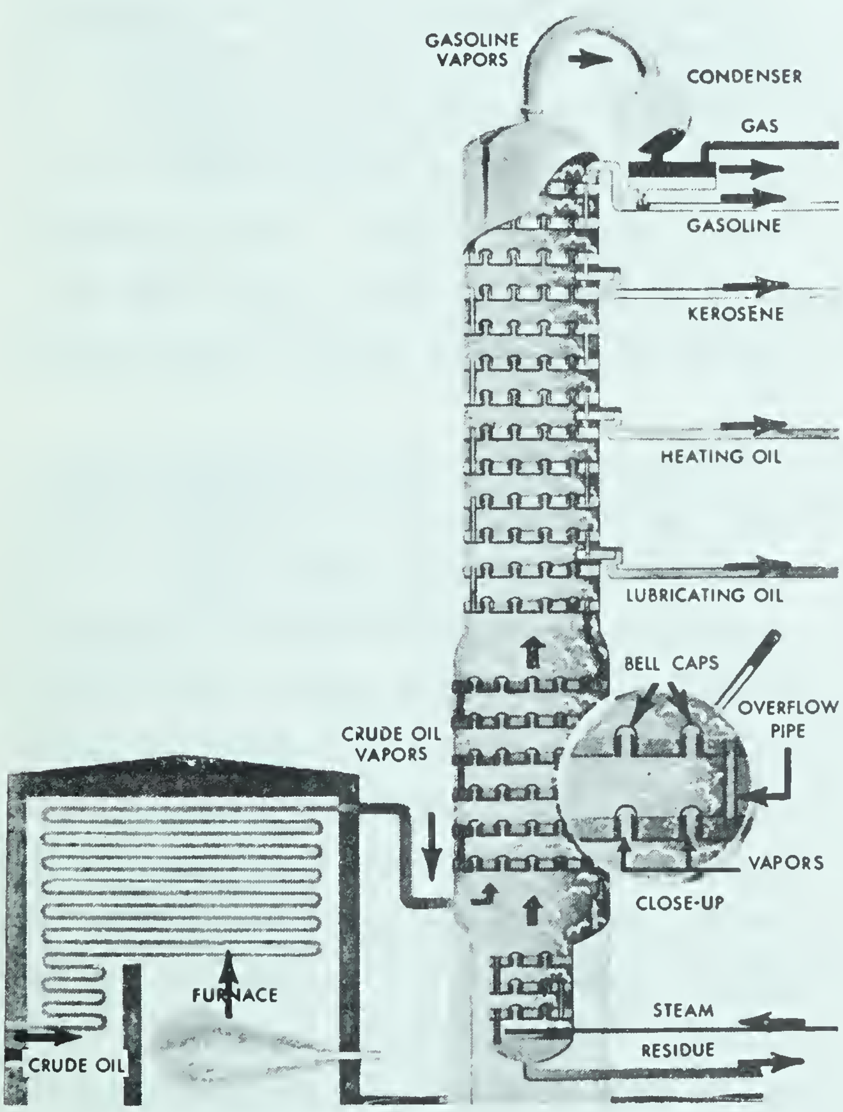


Fig. 20-17. This is a diagrammatic representation of a fractionating tower.

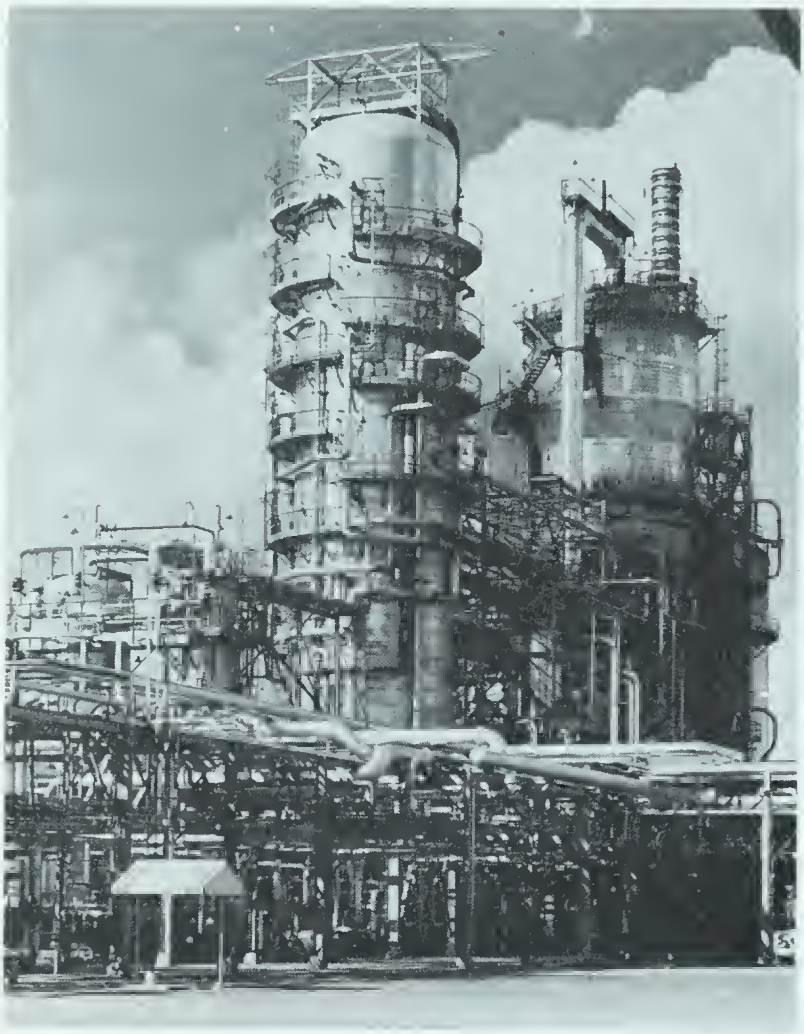


Fig. 20-19. This is a catalytic cracking unit. What advantage does gasoline produced by cracking have over gasoline produced by refining?

with the highest boiling points, are drawn off at the bottom, the lightest, with the lowest boiling point, at the top. Heavy fuel oil collects at the bottom, lubricating oil in the next range, then light fuel oil. At the very top kerosene and gasoline, the light fractions, are condensed and drawn off.

With the increasing use in Canada of automobiles, trucks and tractors more and more gasoline is needed. If gasoline could be produced only by distilling it from crude oil greater quantities of crude oil would be required than could possibly be produced and there would be a vast surplus of other products of the refineries. It has therefore become necessary to find other methods than distillation for producing gasoline. The most important of these is known as *cracking*, a method based on the fact that crude oil consists of many different hydrocarbon compounds. For example, natural gas, or methane, has a chemical formula CH_4. This means that one atom of carbon unites with four of hydrogen to form each molecule of methane. The formula for pentane, C_5H_{12}, means that each molecule of pentane consists of five carbon and twelve hydrogen atoms. Theoretically it should be possible to rearrange the union of atoms in each molecule of pentane in such a way that several molecules of methane is produced from it. This can be done by cracking, a method by which the structure of the molecules of the hydrocarbon compounds less in demand are rearranged into those of the compounds for which there is great demand. By means of cracking, the proportion of gasoline produced from crude oil has been greatly increased. Such gasoline is of a higher quality than that produced by distilling directly from crude oil.

This is a very much simplified picture of the process of refining which does not tell all the story. Some of the petroleum products that are separated in the fractionating tower are chemically treated to remove or convert minor impurities. Others, like lubricating oil, are redistilled to produce different grades of the product. There are other processes too complex to be treated here, each a necessary step in the processing of the many hundreds of important products derived from petroleum.

REVIEW QUESTIONS

1. What does the oil man mean by a "fraction"? **2.** In what important way does each fraction differ? **3.** How is this difference made use of in refining? **4.** What is meant by distillation? **5.** How is this principle used in refining? **6.** What is a fractionating column? **7.** What is meant by "cracking"? **8.** What advantages does the cracking process have over distilling? **9.** On what property of crude oil is the cracking method based?

QUESTIONS FOR REVIEW AND DISCUSSION

1. What is the story behind the formation of petroleum?
2. How are reservoirs of crude oil located and tapped?
3. How is crude oil broken down into marketable components? Name four such components.
4. Find out what the various methods of transporting refined oil are.
5. Name some of the many products which are manufactured from raw materials derived from petroleum. Some of these are mentioned in Unit 14; others you will discover by reading and enquiry.

SPECIAL REPORTS AND PROBLEMS

1. There are two principal methods employed in cracking crude oil: thermal and catalytic. Report to the class on catalytic cracking.
2. Three other treatments are given lubricating oil after fractionating: solvent, refining, dewaxing, and filtering. Read and report on these.
3. A fairly recent development of the oil industry has been the manufacture of new products derived from petroleum. List as many of these as you can find.
4. Many service stations sell two qualities of gasoline, "regular" and "extra." The principal difference between them is the octane number. Report to the class on octane number.
5. One of the many amazing things about the petroleum industry is that the oil is rarely seen until it appears in its final form. Construct a chart to show the path followed by crude oil from the well to an ultimate consumer; for example an automobile or an oil furnace.

TESTING THE PURPOSES OF THIS UNIT

1. What is the meaning of each of the following words or terms: oil seeps, distillation, asphalt, refinery, crude oil, hydrocarbon compounds, marine plants, sedimentary rocks, strata, oil pool, outcrop, geophone, seismograph, cable tool drilling, kelly, drill pipe, bit, spudding in, rotary table, Christmas tree, fractionating column?

2. Is there an oil refinery near your community? If not where is the closest refinery? What are some reasons why it was built there?

3. By what means does the crude oil arrive at this refinery? From what oil fields does the crude oil generally come? What different means of transporting the crude oil were used from the moment it left the well till it arrived at the refinery?

4. What oilfield is closest to your community? How far is this from the sea? If, as is generally believed, oil was first formed under the sea, how do you account for its presence in central Canada? What general conclusions about the prairie provinces do you draw from this fact?

5. What processes are carried out in the refinery closest to your community?

6. What do each of the following sciences study and what contribution does each make to the exploration and production of oil: geology, palaeontology, chemistry, physics, geophysics?

7. Why is oil found concentrated in relatively small areas? What types of rock formation commonly trap oil? How were such traps formed?

8. What important part does mud play in drilling an oil well?

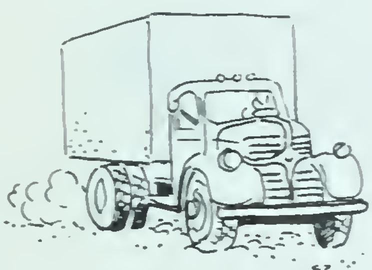
9. When oil has been found, how is the well equipped to control the flow? Does a well which flows naturally at the beginning continue to do so? If not, what means is commonly employed to produce oil from the well? When this fails, what secondary recovery methods are sometimes used to keep the well in production?

10. What conservation practices are now used by the oil companies to improve and maintain production of an oil field?

The old

PRIMITIVE MAN CARRIED BURDENS ON HIS OWN BACK. HIS bare hands were the only source of power he possessed. Gradually he invented a few simple machines like the lever and the inclined plane. He learned to domesticate animals and use them to help in his tasks. But as late as a hundred years ago only about one third of all work done in Canada was performed by machines. The rest was done by men, women, children, and draft animals.

The new



THE DISCOVERY OF PETROLEUM, AND THE VARIOUS PRODUCTS refined from it, stimulated the invention and development of machinery. Gasoline permitted high speed, long-lasting and efficient internal combustion engines to be used in more types of machines, and proper lubricants caused them to perform more efficiently.

Today, in Canada, there are three tractors for every four occupied farms. Farm mechanization makes it possible to produce much more food with less labor by fewer men. Almost half of the houses in Canada are heated by oil and in the factories workmen use machines to turn out more goods to a greater value than men working alone without machines could possibly produce. In a country like Canada, where the distances are great and the population small, where there is a high degree of industrialization and a large proportion of the land devoted to agriculture, oil is of the greatest importance. Canadians are, per person, the second highest consumers of petroleum in the world.

Perhaps you have read references to the "age of leisure" in which we live. Certainly life is much easier today than it was even seventy-five years ago. We owe much of this new leisure to the increased use of machinery.

BIOGRAPHICAL GLOSSARY

Archimedes (287-212 B.C.), a Greek mathematician and physicist who discovered the principle that any body which is held under water weighs just as much less as the weight of the water which it displaces. This is called Archimedes' Principle. He also invented several useful machines for drawing water and for lifting ships out of water.

Aristotle (384-322 B.C.), Greek philosopher who studied nature closely and worked out a system of classification of plants and animals on the basis of their structure. He is considered to be the father of biology.

Bacon, Francis (1561-1626), English philosopher, statesman and scientist. He was one of Queen Elizabeth's counsellors and Lord Chancellor of England under James I. He was a strong advocate of research as the foundation of knowledge.

Beebe, William (1877-), an American scientist, explorer, and author, is a curator of ornithology at the New York Zoological Society. His expeditions have carried him to many parts of the globe.

Bell, Alexander Graham (1847-1922), inventor of the telephone (1875), was one of the world's greatest benefactors. From his invention there have developed transcontinental and transoceanic communications which are now a vital part of our daily life.

Bessemer, Henry (1813-1898), an English engineer, invented a process for making steel which completely revolutionized the industry. In 1865, in his factory at Sheffield, England, he built a furnace called the Bessemer converter, which could produce in ten minutes steel which it would have taken a month to convert by the old process. The first Bessemer converter in the United States was set up at Troy, New York, in 1864.

Burbank, Luther (1849-1926), called the "wizard of the plant kingdom," put to practical use the laws of inheritance and produced many new and valuable fruits and vegetables. Among them are the spineless cactus, the white blackberry, and the Burbank potato.

Comstock, John Henry (1849-1931), American entomologist whose writings added considerably to the knowledge of the field.

Curie, Mme. Marie (1867-1934), a French physicist of Polish birth, who with her husband, Pierre Curie who died in 1906, carried on research which later led to the discovery of the element radium. She twice won the Nobel prize in physics, in 1903 and 1911.

Daguerre, Louis Jacques Mande (1789-1851), a French inventor and scenic painter who is best known for his pioneer work in photography which he shared with his friend, Niepce. Niepce was a chemist and together they invented the process of making sun pictures and fixing them so that they would not fade. After the death of Niepce, Daguerre carried on alone. He was recognized by the Academy of Sciences in France, and his pictures were called daguerreotypes.

Darwin, Charles (1809-1882), an English scientist whose theory of the origin of life completely altered modern thought, spent fifty years of careful and painstaking research before making his announcement. His *Origin of Species*, published in 1859, set forth his theory of evolution.

Edison, Thomas Alva (1847-1931). Although his formal education consisted of only three months in the public school, he continually studied and experimented in his spare time. Among the many contributions this American inventor made are the carbon transmitter in 1877, the phonograph in 1877, the "Ediphone," and the incandescent lamp in 1879. In 1891, he applied for a patent on a camera for taking motion pictures, and later for a projector to throw them on a screen.

Einstein, Albert (1879-1955), a great German physicist, lived as a boy in Munich, and later went to Zurich to study. About fifty years ago, Einstein predicted the relationship between matter and energy. In the last twenty years, his prediction has proved to be true. After leaving Germany, he became head of the school of mathematics of the Institute for Advanced Study, Princeton, and was there up to the time he died.

Fahrenheit, Gabriel Daniel (1690-1736), a German instrument maker who made the thermometer which is named for him. The scale on this instrument is the one used in this country, although the Centigrade scale is more widely used in Europe. Fahrenheit was also the first person to use mercury instead of spirits of wine in his thermometers.

Faraday, Michael (1791-1867), an English scientist, performed an experiment in 1831 which proved that an electric current could be produced by moving a magnet through a coil of copper wire. This discovery introduced the electrical age, for it led to the development of the motor, the dynamo, the induction coil, the transformer, and the X ray.

Fleming, Sir Alexander (1881-1955), an English bacteriologist, is known for his discovery of penicillin. While doing research work on influenza, a mold developed by accident on a staphylococcus culture plate. By further experimenting, he found that a liquid mold culture, which he named penicillin, prevented staphylococcus and many other disease germs from multiplying. In 1945, Fleming shared a Nobel prize for his contribution to science.

Franklin, Benjamin (1706-1790), a distinguished American statesman as well as scientist, discovered by flying a kite in a thunderstorm that the electricity in the lightning flash is the same as that on earth; that is, that lightning and electricity are the same thing. Besides his other interests, Franklin developed the lightning rod and a stove which was given his name.

Fulton, Robert (1765-1815), one of America's early inventors, made and sailed the first successful steamboat. Launching it on August 17, 1807, he made the trip on the Hudson River from New York City to Albany. Thus a new era in transportation was begun.

Galilei, Galileo (1564-1642), an Italian scientist, made important contributions to both astronomy and physics. Making his own telescope, he observed the movements of the planets until he concluded that they moved about the sun instead of about the earth, which was the common belief at that time. By experiments conducted on the Leaning Tower of Pisa, he discovered the laws of falling bodies. He also made the first thermometer and discovered the laws of the pendulum.

Gesner, Abraham (1797-1864), Canadian geologist who made a geological survey of New Brunswick and Prince Edward Island. In 1852 he discovered kerosene oil and introduced its use into the United States.

Gorgas, William Crawford (1854-1920), American disease and sanitation expert, surgeon general of the United States. Sent to the Isthmus of Panama in 1904, he succeeded in

cleansing the Canal Zone of yellow fever by eliminating the breeding places of mosquitoes and segregating stricken patients.

Hooke, Robert (1635-1703), an English mathematician, combined lenses to make an instrument somewhat like the modern compound microscope. With it he made a study of cork, and in a short time discovered the boxlike structures which he called cells. As a matter of fact, he saw only the cell walls of cellulose, not protoplasm or the living part of a cell. But in *Micrographia*, published in 1665, he included pictures of them, the first to be made.

Langstroth, Lorenzo (1810-1895), a schoolteacher whose hobby was bee-keeping. He invented the modern beehive which permits the bee-keeper to open the hive and examine it.

Lavoisier, Antoine (1743-1794), a French chemist, is often called the "father of modern chemistry." From experiments in burning he discovered and named oxygen, hydrogen, and nitrogen. He also determined the true nature of combustion. His account of his experiments was the first textbook in chemistry. Lavoisier worked to improve agricultural methods by establishing government agricultural stations; and, in an entirely different field, he devised methods of savings and savings accounts. Despite all these contributions, he was considered an aristocrat during the French Revolution and, twenty years after his discoveries, was arrested and beheaded.

Lazear, Jesse William (1866-1900), American physician who served as a member of the Yellow Fever Commission in Cuba. Bitten by a carrier mosquito he contracted yellow fever and died.

Leeuwenhoek, Anton van (1632-1723), a Dutch naturalist, by grinding and mounting his own lenses, perfected a microscope with which he could see microorganisms. These bacteria he called "little animals." He made drawings of heart muscles, plant tissue, and bacteria which were very accurate.

Linnaeus, Carolus (1707-1778), Swedish botanist, founder of modern systematic botany. He discarded the common names of plants and gave each one a scientific name taken from the Latin. The scientific name of each plant had at least two parts. He also published a list of scientific names for animals.

Marconi, Guglielmo (1874-1937), an Italian engineer, is the inventor of wireless telegraphy. From Newfoundland, in 1901, he received signals sent across the Atlantic. Sending up a kite equipped with a wire leading from a telephone receiver, he received the three faint taps which meant the letter *S* of the Morse code sent to him from England. In time wireless began to serve the world in many ways, and during World War I Marconi had charge of all the wireless operations of Italy. In 1909 he was awarded the Nobel prize, and in 1912 he was recognized by his nation and made a member of the Italian Senate.

Mendel, Gregor (1822-1884), an Austrian monk, whose hobby was botany, discovered the most important laws of inheritance. Experimenting with garden peas, he discovered that when two different varieties were crossed, the "offspring" plant bore the characteristics of one parent plant. Those traits which were retained he called "dominant"; those lost, he called "recessive." The new generation with traits distinctive to itself was composed of hybrids. Proceeding on his theory, he mated the hybrids and found that the

recessive traits reappeared in the offspring. He published his findings in 1865, but it was not until 1900 that his obscure book was found and his theories acknowledged as true. His interpretations have proved to be the foundation of the modern theory of heredity.

Morse, Samuel F. B. (1791-1872), an American artist and inventor, was one of America's earliest portrait painters. But being of an inventive turn of mind, he conceived the idea of the telegraph. After he had perfected his instruments, Congress appropriated, in 1843, $30,000 for the construction of a telegraph line from Washington to Baltimore. In May, 1844, the first public message was sent over the wire: "What hath God wrought?" Somewhat later he laid the first submarine telegraph line in New York harbor.

Newton, Sir Isaac (1642-1727), an English physicist and mathematician who worked out the laws of gravity and gravitation. Because he saw an apple fall from a tree to the ground one day, he began thinking and experimenting on why things fall. The laws which he worked out account not only for the falling of objects on earth, but also pertain to the heavenly bodies. He also worked on the subject of light, showing that it is a mixture of different colored rays. He studied motion and brought forth the Laws of Motion which are named for him.

Piccard, Auguste (1884-), of Swiss descent, is a professor of physics at Brussels University. He is famous for his balloon ascents into the stratosphere. In October, 1934, he reached an altitude of 57,579 feet. He also developed the bathyscaphe, in which he went down 13,283 feet below the surface of the Mediterranean Sea.

Torricelli, Evangelista (1608-1647), an Italian physicist and assistant to Galileo, discovered the principle of the barometer. While investigating the fact that a pump would not lift water from a depth of more than thirty feet, he discovered that this depth is that of a column of water whose downward pressure equals the atmospheric pressure against it. From this principle he constructed the first barometer. Later he improved the microscope, and he also made discoveries in mathematics and physics. Upon the death of Galileo he was appointed to take his place as professor of philosophy and mathematics in the Florentine Academy.

Watt, James (1736-1819), a Scottish engineer, may well be called the father of the age of power, for his developments in steam engines. He improved the early engines and made them practical. Experimenting first with a Newcomen engine, he constructed an engine of his own on which he took out his first patents in 1769. With Matthew Boulton, he established a plant in London which soon became famous all over Europe for its steam engines.

Wright, Orville (1871-1948), with his brother Wilbur, experimented with gliders and power machines until on a day in December, 1903, at Kitty Hawk, North Carolina, they made the first flight in a plane carrying a man. The distance was only 120 feet and it was covered in twelve seconds, but it established the airplane as certain to be a new mode of transportation and the Wright brothers as the pioneers in this new field.

Wright, Wilbur (1867-1912), made his first public flight in France, in 1908. The next year the Wright brothers were awarded gold medals by the French Academy of Science, and their machine was accepted by the United States Government for army use. In December, 1928, the first flight was commemorated at Kitty Hawk and a monument was erected on the site.

Young, James (1811-1883), Scottish industrial chemist. He patented a process for distilling bituminous substances to produce oils, naphtha and paraffin.

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Absolute humidity, amount of water vapor a unit volume of air contains at any given time.

Acid, compound containing hydrogen whose water solution tastes sour and changes blue litmus to red.

Acceleration (ak-sel-uh-*ray*-shun), the rate of change of speed.

Aeration, process of mixing air with water.

Aerial, radio antenna.

Agar (*ah*-gar), white powder from seaweeds used as a culture medium.

Ailerons, small structures hinged to the back of an airplane wing to bank the plane.

Air mass, a large volume of air that has the same characteristics throughout.

Air pressure, force which air exerts on a unit area of the surface it touches.

Airfoils, propeller, wings, tail, and other surfaces which help to support the plane in flight.

Alkali (*al*-kah-lye), any solution that will turn red litmus blue.

Alloy, substance which contains a uniform mixture of two or more metals, usually formed by melting the metals together.

Alternating current, current which flows back and forth in a circuit, constantly and rapidly changing its direction.

Altimeter (al-*tim*-ih-ter), a form of barometer used to measure altitude.

AM radio, amplitude modulation broadcasting, or standard radio broadcasting.

Ammeter (*am*-mee-ter), instrument for measuring the rate of flow of electric current flowing in a circuit.

Ampere (*am*-peer), unit of rate of flow of an electric current.

Amplitude, loudness of sound.

Antenna, special type of conductor for sending and receiving electric waves.

Anther, part of the stamen which bears the pollen grains.

Anthracite coal, hard coal.

Anticline, the crest of an arch of rock folded upwards by an upheaval of the earth.

Apiary (*ay*-pi-airy), a collection of hives or colonies of bees kept for their honey.

Aqueous (*ay*-kwee-us) **humor,** liquid which fills space between cornea and lens of eye.

Archimedes' Law, loss of weight of a submerged body is equal to the weight of the liquid or gas displaced.

Armature (*arm*-uh-ture), the part of an electric device which moves by magnetism.

Artificial selection, the selection of best seeds to produce the next crop.

Asteroids, tiny planets whose paths of revolution around the sun lie between the orbits of Mars and Jupiter.

Astronomy, the branch of science which studies the heavenly bodies.

Atmosphere, whole mass of air surrounding the earth.

Atom, smallest part of an element that has the properties of that element.

Atomic weight, the weight of a given atom compared to the weight of an oxygen atom considered as 16.

Audio frequency, term used in radio to indicate the rate of sound vibrations less than 20,000 per second.

Axon, process of a nerve cell.

Bacteria, smallest and simplest of plants, seen only with a microscope.

Balance, instrument for weighing objects which compares a known weight with an unknown weight.

Barometer, an instrument that measures air pressure.

Base, compound of a metal and one or more OH radicals whose water solution tastes bitter and changes red litmus to blue.

Beam of light, several rays of light.

Beats, alternate increasing and decreasing of loudness of two tones.

Bituminous coal, soft coal.

Blast furnace, furnace in which iron is separated from its ore.

Brushes, carbon devices for removing current from the armature of a generator, or leading current into the armature of a motor.

Btu, amount of heat needed to raise the temperature of one pound of water one degree on the Fahrenheit scale.

Budding, the uniting of a bud with a stock.

Bulb, a large underground bud protected by scales.

Buoyancy (*boy*-an-see), the net upward force exerted on a submerged or floating object by a liquid or gas.

Calorie (small), quantity of heat needed to raise the temperature of one gram of water one degree on the Centigrade scale.

Calorie (large), quantity of heat needed to raise the temperature of 1,000 grams of water one degree on the Centigrade scale.

Candle power, amount of light given out by an object compared to the light from a standard candle.

Capillary action, rising of liquid in long, thin spaces.

Carbohydrate (*kar*-boh-*high*-drate), any chemical compound such as sugar or starch. which contains carbon, hydrogen, and oxygen.

Carburetor (*kar*-buh-ray-tor), device for mixing gasoline vapor with air before exploding it in the cylinders of a gas engine.

Carrier wave, radio wave which carries a message through space.

Cast iron, pig iron which is remelted and cast into molds for industrial uses.

Ceiling, height of the clouds.

Cell, unit of structure of all living things.

Cell wall, outer, nonliving wall secreted around plant cells.

Center of gravity, where the body balances.

Centigrade, thermometer scale graduated in 100 degrees with freezing and boiling points of water 0° and 100° respectively.

Centrifugal (sen-*trif*-you-gul) **force,** force which is directed outward when an object moves in a curved path.

Chain reaction, one which is continuously repeated because something needed to cause the reaction is given off by the reaction itself.

Chemical change, a change which results in the formation of new substances with completely different properties.

Chemical composition, the kinds and amounts of elements in a substance.

Chlorination (kloh-rin-*ay*-shun), addition of chlorine to water in order to kill germs.

Chlorophyll (*kloh*-roh-fill), green coloring matter in plants.

Chloroplasts, small bodies in the cell containing chlorophyll.

Christmas tree, mechanism to control the flow of oil from a well.

Chronometer (kroh-*nom*-ih-ter), a special clock which keeps time accurately.

Circuit (*sir*-kit), complete path through which the electric current flows.

Clay, decomposed feldspar.

Climate, the seasonal average weather conditions over very long periods of time at a given place.

Coagulation (*koh*-ag-you-lay-shun), the formation, by chemical reaction, of a jellylike material in water, often used to remove fine sediment from water.

Coke, product formed by heating coal in absence of air.

Cold front, a mass of cold air overtakes a mass of warm air.

Combine, a machine which harvests and threshes grain while moving over the field.

Combining bond, a link joining atoms together when showing atomic arrangement.

Combining number, the number of hydrogen atoms that join with one atom of another element.

Combustion, a chemical change, such as burning, in which heat and light are produced.

Comets, large heavenly bodies composed of gaseous matter.

Combustible, will burn at ordinary temperatures.

Commutator (*kom*-mew-tay-tor), a device for reversing the direction of an electric current in a motor or generator.

Compass, instrument which indicates direction by a magnetic needle.

Complementary colors, any two colors that combine to produce white light.

Compound, a material composed of two or more elements chemically combined.

Compound machine, combination of two or more simple machines used for some special purpose.

Compressed air, air under more than ordinary pressure.

Compression (kom-*preh*-shun), that part of a sound wave where the particles are pushed close together.

Concave lens, lens which is thinnest in the middle; curved inward.

Condensation (kon-den-*say*-shun), changing of a vapor into a liquid by cooling.

Conduction, transfer of heat by two objects in contact, or between parts of the same object by molecular collision.

Conductor, any substance that easily carries an electric current.

Conduits (*kon*-dew-its), pipes enclosing electrical wires.

Conservation, the preservation and wise use of natural resources.

Constellation, group of stars forming a pattern.

Contour farming, plowing around hills instead of up and down them, so as to conserve moisture and prevent erosion.

Controlled experiment, experiment where only one factor is allowed to change in the same trial.

Convection (kon-*veck*-shun), the transfer of heat by the natural motion of gases and liquids.

Convection currents, motion of gases and fluids set up by unequal pressure.

Converter, large furnace in which Bessemer steel is made.

Convex (*kon*-vecks) **lens,** lens which is thickest in the middle; curved outward.

Corm, a shortened underground stem in which the leaves are reduced to thin scales.

Cornea (*kor*-nee-ah), the outer, transparent protective covering of the eye.

Corona (koh-*roh*-nah), band of light around the sun seen during an eclipse and caused by incandescent vapors from the sun.

Corrode, to eat away by chemical action.

Cotyledons (*kot*-ih-lee-dons), seed leaves, a part of the embryo of a plant containing stored food.

Cover crops, those which cover the land and thus decrease erosion.

Cracking, method of treating crude oil to obtain gasoline.

Crop rotation, planting different crops on the same land each year.

Cross-pollination, transfer of pollen from the anther of one plant to stigma of another plant.

Crucible (*kroo*-sih-bul), hollow container such as the bottom of a blast furnace which receives the molten metal.

Crude oil, the form in which mineral oil is found.

Cyclone (*sy*-klone), low-pressure area.

Cyclotron (*sy*-kloh-tron), atom-smashing machine.

Cylinder, round chamber in an engine or some types of machines.

Deciduous trees (de-*sid*-u-us), trees that lose their leaves in autumn.

Declination (deck-lin-*ay*-shun), the variations of the N pole of the magnetic needle from the true north-south line.

Degree (thermometer), a unit determined by dividing evenly the space between the melting and boiling points.

Derrick, the tower-like structure which supports the tools for drilling a well.

Dew point, the temperature to which the air must be cooled in order to cause gaseous water vapor to condense into liquid water.

Diffusion, "bounding back" in all directions of rays of light striking a rough surface.

Digestion, change of an insoluble food to a soluble form.

Direct current, electric current which flows through a circuit in one direction only.

Direct lighting, light passing directly from the source of illumination to the object.

Distillation, process of purifying liquids by heating them until they form a vapor, and then condensing the vapor by cooling.

Drag, the resistance offered by the air to an airplane which is moving through it.

Dry cell, electric cell sealed in a metal can.

Dry farming, stirring the surface of the soil to keep the top layer broken into fine particles to conserve moisture.

Dynamo, machine which changes mechanical energy to electrical energy.

Eardrum, the part which separates the outer ear from the middle ear.

Earthquake, result of the movement or tremor of the earth's crust.

Eccentric (eck-*sen*-trick), wheel with axle off-center.

Echo, reflected sound, reaching a person more than $\frac{1}{10}$ of a second after the original sound was made.

Eclipse, phenomenon in which the moon passes between the sun and the earth, or in which the moon enters the earth's shadow.

Effervesce (*ef*-fer-vess), to bubble or give off gas.

Egg, female reproductive cell.

Electric current, flow of electrons along a conductor.

Electric meter, instrument for measuring the amount of electric energy used.

Electrolysis, separating a chemical compound into its parts by using an electric current.

Electromagnet, soft iron core with a coil of insulated wire around it carrying current.

Electron, one of the particles of an atom having a unit charge of negative electricity.

Electronics, science dealing with the use and control of electrons in vacuum tubes.

Electroplating, depositing pure metal on an object with an electric current.

Element, a form of matter which cannot be divided into any simpler form of matter by ordinary chemical means.

Embryo (of plant), complete young plant found in a live seed.

Energy, ability to do work.

Engine, any type of compound machine which converts heat into mechanical energy.

Environment, all the matter and forces around you.

Enzyme (*en*-zyme), special substance manufactured in almost all cells of plants and animals, which controls digestion and various other cell activities.

Epidermis, outer layer of tissue.

Equation, a shorthand method of showing how atoms rearrange themselves during a chemical change.

Equator, imaginary circle around the earth, equidistant from the two poles.

Erosion, the moving of soil by running water, wind, waves, or ice.

Evaporation, process of changing a liquid into a vapor.

Exoskeleton, the hard, outer covering of an organism.

Fahrenheit, a thermometer scale ranging from 32 degrees as freezing point of water to 212 degrees as the boiling point of water.

Farsightedness, condition of the eye when light rays come to a focus back of the retina, and near objects are not clear.

Fats, foods consisting of carbon, hydrogen, and oxygen, and containing more than twice as much energy as do the carbohydrate foods for the same weight.

Fault, a rock formation in which a porous layer of rocks lies side by side with a non-porous layer. Also a crack in the earth's surface due to movements of the earth's crust.

Fermentation, process of forming carbon dioxide and alcohol by the action of yeasts on sugars.

Fertilization, union of sperm and egg.

Filtering, process of pouring liquids through a fine sieve or other material so that solid particles are removed.

Fire, burning of some fuel.

Fission, nuclear, the breaking apart of a heavy atom like uranium into two other large atoms of different elements.

Flame, burning gas.

Flower, organ for reproduction in flowering plants.

Fluid friction, friction that occurs when an object moves through a fluid.

Fluorescent (flew-or-*eh*-sent) **light,** that which is produced by minerals which glow when exposed to invisible ultraviolet light.

FM radio, frequency modulation broadcasting.

Focal length, distance from the principal focus to center of lens.

Focus, point where all parallel rays passing through a lens are brought together.

Food, any substance absorbed into the body which yields material for energy, growth, and repair without harming the organism in any way.

Foot candle, light intensity at any given point one foot from a standard candle.

Foot pound, unit of work accomplished when a force of one pound moves an object a distance of one foot.

Forage crops, crops used for feeding livestock.

Force, push or pull.

Force of gravitation, pull of all bodies or particles of matter toward each other.

Force of gravity, pull of the earth which is exerted on all bodies.

Formula, a combination of symbols representing an element or a compound and showing its composition.

Formula weight, the sum of the weights of all the atoms in a formula.

Fossils, impressions, or permanently hardened remains, of plants and animals of the past preserved in the earth's crust.

Fractionating, the process by which the hydrocarbon compounds contained in crude oil are separated into different parts or fractions.

Frequency of vibration, the number of times an object vibrates per second.

Friction, a force which resists motion.

Fruit, ripened ovary with or without associated parts.

Fulcrum, point or support about which a lever turns.

Fumigation, the act of applying smoke, vapor, or gas, to destroy insects or to disinfect clothing or other articles.

Fungicide (*fun*-ji-side), any substance that destroys fungi or inhibits the growth of the spores.

Fundamental, lowest tone produced when a wire or sounding body vibrates.

Fungus, nonflowering plant lacking chlorophyll and living on organic matter.

Fusion, nuclear, the combining of two, or more, light atoms to make an atom of another element.

Galvanometer (gal-vuh-*nom*-eh-ter), instrument for measuring the strength of a weak electric current.

Gas, substance which has neither a definite shape nor a definite volume.

Generator, machine for changing mechanical energy into electrical energy.

Geology, the science of the structure of the earth.

Geophones, sensitive detectors which pick up sound reflected from rock layers.

Germination (jer-min-*ay*-shun), growth of the seed when favorable conditions occur.

Glacier (*glay*-shur), huge mass of ice and snow formed in mountains and moving slowly down into valleys.

Grafting, union of the inner bark of a live twig with the tree on which it is to grow.

Gravity, force of attraction which pulls things to the earth.

Ground waves, radio waves which follow the curve of the earth.

Guard cell, one of the two epidermal cells surrounding a stomate.

Gusher, a spout of petroleum forced up by great pressure.

Hard water, water containing dissolved mineral matter which makes soap curdle.

Heat, sun radiations which raise the temperature, or we can say a form of energy.

Heat waves, waves which vibrate slower than light waves.

Herbicide, a chemical compound used to destroy plants.

High-pressure area, a region of air, usually cool and dry, with higher pressure than the surrounding air.

Horsepower, unit for measuring power. It is 550 foot-pounds of work per second, or 33,000 foot-pounds per minute.

Host, any organism living or dead which acts as a source of food for another plant or animal.

Humid, condition in which air contains much water vapor.

Humidity (hew-*mid*-ih-tee), moisture content in the air which is in the form of water vapor.

Humus (*hew*-mus), dark upper layers of original soil composed chiefly of decayed and decaying parts of animals and plants.

Hurricane, a storm, usually starting over water, extending several hundred square miles in area.

Hybrid, the offspring of two parents of different varieties.

Hydraulic (high-*draw*-lick), pertaining to water, or other fluids.

Hydrocarbon, a compound of the elements hydrogen and carbon.

Hydroxide group, the OH group in all bases.

Hygrometer (hy-*grom*-ih-ter), instrument which measures humidity.

Hypha (*high*-fah), a threadlike filament of the vegetative body of a fungus.

Hypocotyl (*hy*-poh-kot-ill), part part of a plant embryo from whose lower end the root develops.

Iconoscope (eye-*kon*-oh-scope), the tube in the television camera which takes the picture.

Igneous (*ig*-nee-us) **rock,** rock which has been formed by the cooling of hot, liquid material from the interior of the earth.

Incandescence (in-kan-*deh*-sense), glowing of a wire or other matter when it is white-hot.

Incident rays, rays of light striking a surface.

Incombustible, will not burn at ordinary temperatures.

Induced current, current produced when a wire which is part of a complete circuit cuts magnetic lines of force.

Inertia (in-*er*-shuh), tendency of a body at rest to remain at rest, or of a body in motion to remain in motion in a straight line with uniform speed.

Inorganic, pertaining to nonliving things.

Input, work put into a machine.

Insecticide, a chemical preparation in form of liquid or powder used to deter or destroy insects.

Insoluble substance, that which will not dissolve when placed in a liquid.

Insulator, any material which does not conduct heat or electricity readily.

Internal combustion engine, engine which vaporizes the fuel, mixes it with air, compresses the air and fuel, burns the fuel, and removes the products of combustion.

Interval, the difference in vibration rates between two musical notes.

Ionosphere layers, those that reflect the sky waves back to earth.

Iris, colored part of the eye.

Irrigation, artificial watering of crops.

Jet engine, one whose thrust is produced by the force of unequal pressures in the explosion chamber.

Kelly, steel bar which is part of the mechanism involved in drilling for oil.

Kilowatt-hour, unit used for measuring electrical energy; equals 1,000 watt hours.

Kindling temperature, lowest temperature at which a fuel will take fire and continue to burn.

Kinescope, apparatus in television receiver; the picture tube.

Kinetic (kin-*et*-ick) **energy,** energy a body has because of its motion.

Land breeze, winds blowing from the cold land toward the warmer water.

Larva, the caterpillar or grub state of an insect; the first stage after the egg.

Latitude, distance in degrees measured north or south of the equator.

Lava, hot, liquid rock arising from a volcano.

Layering, the development of roots from the stem where it contacts the ground.

Leaves, the part of a green plant in which most of the food is manufactured.

Lens (*lenz*), the part of the eye lying just behind the pupil opening of the iris.

Lever, simple machine consisting of a rigid bar which is free to turn about a fixed point, the fulcrum.

Lift, the upward force exerted on the wings of an airplane because of moving air.

Light, radiations from the sun and other objects which affect the eye.

Light beam, several rays of light.

Light waves, waves capable of producing vision.

Light year, the distance light travels in one year, approximately six trillion miles.

Lines of force, imaginary curved lines that leave the north pole of a magnet, pass through air, and re-enter the magnet at the south pole.

Liquid, a substance which has a definite volume, and takes the shape of its containers.

Longitude, the distance in degrees east or west of the prime meridian running through Greenwich, England.

Loud-speaker, device for changing an audio signal into sound waves.

Low-pressure area, a region of air, usually warm and damp, with lower pressure than the surrounding air.

Luminous, giving out light of its own.

Machine, any mechanical device man uses to help him do work.

Magnetic field, any space through which magnetic lines of force pass.

Magnitude, brightness of a star according to a set scale.

Malleability (mal-ee-ah-*bill*-ih-tee), the ability of a metal to be molded into shape by pressure.

Matter, anything which occupies space and has weight.

Meridian, imaginary line passing through the North and South poles and any given place.

Metal, any chemical element which conducts heat and electricity well, and usually has a metallic tinkle and luster.

Metamorphic (met-ah-*mor*-fick) **rock,** rock which has been changed under great pressure and heat.

Metamorphosis (met-ah-*mor*-foh-sis), development of the mature insect by passing through several distinct stages.

Meteorites, remnants of the original meteor which strikes the earth's surface.

Meteors, small bodies that become visible when they strike the earth's atmosphere.

Microphone, instrument which changes sound waves into audio-frequencies which are then combined with the carrier frequency in radio broadcasting.

Microorganism, a small plant or animal of such size as to be visible only through a microscope.

Microwaves, radio waves with very short wave lengths.

Mimicry (*mim*-ik-ree), a resemblance of one organism to another.

Mineral, any chemical element or compound occurring naturally in the earth.

Mixture, a substance containing two or more elements or substances that have intermingled without a chemical change. Each material retains its own original properties.

Molecule (*moll*-uh-kule), the smallest quantity of any substance which exists and has the properties of that substance.

Molds, nongreen plants belonging to the fungi group.

Molecular formula, a group of symbols and figures used to represent one molecule of an element or compound.

Molecular weight, the sum of the weights of all the atoms in a molecule.

Mulch, covering on the soil of some material such as straw, leaves, or grass to keep soil water from evaporating.

Mycelium (my-*see*-lee-um), the mass of thread-like filaments that makes up the main body of a fungus.

Natural resources, wealth of a nation in terms of its water, minerals, soil, and wildlife.

Nearsightedness, condition of the eyes when light rays come to a focus in front of the retina and distant objects are not clear.

Neutron (*new*-tron), one of the particles in the nucleus of an atom having no electrical charge.

Nitrogen-fixing bacteria, those living in nodules on the roots of leguminous plants and having the ability to change gaseous nitrogen of the air into soluble salts of nitrogen.

Nonmetal, element usually lacking a luster and a metallic tinkle.

Nucleus (of atom), the central part of the atom.

Nucleus (of cell), the darker central part of the cell which is the center of cell reproduction.

Nymph (nimf), a young insect that resembles the adult in most of its characteristics.

Octave, an interval in which the high tone has a vibration rate twice as great as that of the low tone.

Ohm (*ome*), unit of electrical resistance.

Opaque (oh-*pake*), objects that don't permit light to pass through them.

Ore, compound of a metal or mineral which has undesirable substances mixed with it, and from which the metal can be extracted profitably.

Organic, pertaining to living things, both plant and animal.

Osmosis (ahs-*moh*-sis), passing of liquids through membranes from a region of greater concentration to a region of lesser concentration.

Outcrop, the exposed section of a layer of rock.

Output, work done by a machine.

Ovary, basal part of the pistil containing the ovules which become seeds.

Overtone, tone produced when a wire or sounding body vibrates in two or more parts.

Ovule, structure in the ovary of a flower which, when fertilized, can become a seed.

Oxidation (ock-sih-*day*-shun), combining of a substance with oxygen, usually producing heat and light.

Oxide, compound containing oxygen and one other element.

Palaeontology (pay-lay-on-*to*-lo-jee), the science which studies fossils.

Palisade cells, dense tissue in green leaves and twigs consisting of closely packed, elongated cells.

Parallel circuit, circuit in which different quantities of current can flow through the different parts of the circuit.

Parasite, any plant or animal which lives on the tissues of other living organisms and gets its food entirely from the body of the host organism.

Partial vacuum, space in which the air pressure is reduced.

Pendulum, any object which, when suspended from a given point, will swing freely back and forth.

Penumbra (peh-*num*-brah), lighter part of a shadow.

Percussion (pur-*kuh*-shun), sharp strike or blow which sends out vibrations.

Petals, colored parts of a flower.

Petroleum, another name for crude oil.

Photoelectric cell, device which produces a change in an electric current when the light which strikes the cell changes in intensity.

Photosynthesis (foh-toe-*sin*-thih-sis), manufacture of carbohydrate foods by the green cells of a plant, in sunlight.

Physical change, change in the form of a substance without any change in its chemical composition.

Pig iron, iron which comes from the blast furnace, but which still contains carbon and other impurities.

Pistil, part of the flower bearing the ovary at its base.

Piston, solid structure fitting within the cylinder in an engine or a machine, which moves back and forth when driven by some force.

Pitch, the highness or lowness of a sound.

Planet, a large heavenly body which revolves around the sun.

Plumule (*plu*-mule), that part of a plant embryo from which the shoot develops.

Pneumatic (new-*mat*-ick), pertaining to air or air pressure.

Poles, the opposite ends of a magnet.

Pollen, male reproductive cells of flowering plants.

Pollination, transfer of pollen from the anther to the stigma of a flower.

Potential (poh-*ten*-shal) **energy,** stored energy.

Power, rate of doing work.

Precipitate (pree-*sip*-ih-tate), solid substance resulting from chemical changes in a solution; it settles to the bottom.

Pressure, force of water or some other substance against a unit of area, such as the square inch.

Propagation, the act of reproducing.

Protective coloration, the development of a color scheme by an animal to permit it to harmonize with the surroundings.

Proteins, complex class of foods containing carbon, hydrogen, oxygen, nitrogen, sulfur, and sometimes phosphorus; used for building body tissue.

Proton (*proh*-ton), one of the particles of an atom having a unit charge of positive electricity.

Protoplasm (*proh*-toh-plasm), living substance of the cell.

Pruning, cutting away all broken stems and some of the top of woody plants.

Pulley, simple machine consisting of a small wheel with a grooved rim, mounted on a frame in such a way that it can turn easily on a fixed axle.

Pupa, the dormant or resting stage of the life cycle of an insect.

Pupil (eye), round opening of the iris.

Purebred, line which breeds pure.

Pustules (*puhs*-tules), blisters containing ripening spores.

Pycnia (*pik*-nee-ah), receptacles in certain fungi in which spores are contained.

Radar, electrical apparatus for locating the exact position of distant objects on land, in the air, and on water by means of radio waves.

Radiation (ray-dee-*ay*-shun), transfer of energy through space by vibration or wave motion.

Radical, a group of elements that act as a unit in a chemical change.

Radioactive elements, elements which decompose of their own accord, giving off particles and invisible radiations.

Radio frequency, term used in radio to indicate the rate of vibrations higher than 20,000 per second.

Rarefaction (rare-uh-*fack*-shun), that part of a sound wave where the particles are spread farther apart.

Ray, single line of light.

Real image, one which can be projected on a screen or piece of paper.

Reciprocating (re-*sip*-row-kate-ing) **engine,** one that has a piston that travels back and forth in a cylinder.

Reduction, chemical process by which oxygen is removed from a compound.

Refinery, plant where crude oil is purified.

Reflected rays, rays of light bouncing off a surface.

Reflection, "bouncing back" of rays of light, sound waves, or other forms of wave energy.

Reforestation, renewing a forest by seeding or planting.

Refraction, bending of rays of light.

Relative humidity, quantity of water vapor in the air compared to the water vapor the air can hold at that temperature.

Relay, electromagnetic instrument by which the opening or closing of one circuit opens or closes another circuit.

Resistance (electrical), opposition of a substance to an electric current passing through it.

Resistance (force), object to be moved, or the object against which force is applied.

Respiration, process by which all living things take in oxygen and release carbon dioxide and energy.

Retina, inner layer of eye containing nerve endings of sight.

Retorts, closed containers for heating certain materials.

Rhizome (*rye*-zome), an underground stem.

Rocket engine, one in which oxygen necessary to burn fuel is carried with the fuel.

Rolling friction, friction that occurs when one surface rolls over another surface.

Root, organ of the plant below the soil which absorbs liquids and anchors the plant.

Root hairs, tiny cells on the surface of small roots.

Salt, chemical compound often made by the reaction between an acid and a base.

Saprophyte (*sap*-ro-fight), a plant that lives on dead organic materials.

Satellite (*sah*-tel-lyte), any body revolving around a planet.

Saturation temperature, the temperature at which the water vapor in the air begins to condense.

Scan, the rapid movement of the beam of electrons back and forth across the plate 525 times per second in a television tube.

Scarification, the process of making scratches on seed coats.

Science, classified knowledge.

Scientific method, that which allows only one factor to be changed during the trials of an experiment.

Scion (*sigh*-on), the portion of a twig grafted onto a rooted stock.

Sea breeze, a flow of air from sea to land due to unequal pressure.

Sediment, sand, mud, or gravel worn from the earth's surface by water, wind, or frost and deposited in water.

Sedimentary rock, mud, sand, and gravel carried by water in prehistoric times and deposited in layers which are now hard.

Seed, complete embryo plant with stored food and protected by one or more seed coats.

Seedling, young plant grown from seed.

Seep, a spot where petroleum oozes out slowly and gathers in a pool.

Seismic (*size*-mik), having to do with earthquakes.

Seismograph (*size*-mo-graf), an instrument for recording the strength of earthquakes.

Selective cutting, cutting only the mature trees in a forest.

Self-pollination, transfer of pollen from anther to stigma in same flower or another flower of same plant.

Sepal (*see*-pal), outermost part of a flower, usually green and not involved in reproduction.

Series circuit, circuit in which the same amount of current flows through all parts of the circuit.

Sewage, the liquids containing wastes from homes and industries.

Sextant, instrument used in navigation to measure the elevation of the sun and stars.

Shelterbelt, several long rows of trees planted at right angles to the direction of the prevailing wind to prevent wind erosion.

Short circuit, point of low resistance in a circuit.

Shutter, that which controls the length of time the light enters the camera.

Sidereal system, relating to the stars.

Sky waves, radio waves which travel up into the sky.

Smoke jumpers, parachutists who investigate smoke and fight fires in forested areas.

Soft water, free of dissolved mineral matter in which soap immediately forms suds and does not curdle.

Soil, uppermost layers of the earth's crust, derived from rocks.

Soil water, water that sinks into the soil.

Solar spectrum, band of seven colors formed by a beam of sunlight striking a prism.

Solar system, sun and all the bodies which revolve around it.

Solder (*sod*-der), a mixture of lead and tin which melts at low temperature.

Solid, a substance having both a definite volume and a definite shape.

Soluble, capable of being dissolved, usually in water.

Sperm, male reproductive cell.

Spongy cells, loosely constructed tissue in a green leaf.

Spontaneous combustion, fire started by the accumulated heat of slow oxidation.

Sporangium (spoh-*ran*-gee-um), a structure which produces spores.

Spores, small reproductive cells of bacteria, yeasts, and molds.

Stamens (*stay*-mens), parts of the flower bearing anthers at their tips.

Star, heavenly body which gives off light.

Static electricity, electricity at rest.

Steam engine, engine which converts heat into mechanical work by the use of steam.

Steel, alloy of iron, carbon, and various other elements.

Stem, the part that holds up the plant and acts as a delivery system.

Stigma, part of the pistil which receives the pollen grains.

Stomates (*stoh*-mates), pores regulating the passage of air and water vapor to and from the inside of the leaf.

Storm, any disturbance in the atmosphere.

Strata, layers of sedimentary rock.

Stratosphere (*strat*-us-feer), that part of the upper atmosphere in which the temperature is almost uniform and clouds of water never form.

Strip cropping, planting of alternate rows of grasses or grains with other crops.

Structural formula, a diagram showing the arrangement of atoms in a molecule.

Style, stalk of the pistil.

Subsoil, soil below the topsoil.

Sun spectrum, a band of colors formed by a beam of sunlight passing through a prism.

Symbol, a letter or a pair of letters used to represent an atom of an element.

Television, process by which sound and pictures are sent from broadcasting stations.

Temperature, the degree of heat which is measured on some definite scale.

Thorax, the middle region of the body of an insect between the head and abdomen.

Thermoplastic, plastic that can be softened by heating.

Thermosetting, plastic that sets by heating and cannot be softened again.

Thrust, the forward force produced on an airplane by the propeller or jet engine.

Timbre, difference between two sounds of the same pitch and loudness.

Time belt, geographical area in which the same standard time is used.

Tissue, cells of the same kind grouped together.

Topsoil, uppermost portion of original soil.

Tornado, violent, whirling wind moving in a narrow path at high speed.

Translucent (trans-*lew*-sent), any substance permitting some diffused light to pass through.

Transparent, permitting light to pass through without diffusion.

Transpiration, the evaporation of water from leaves of plants.

Troposphere (*traw*-pus-feer), that part of the atmosphere extending from the surface of the earth to an average height of eight to nine miles.

Turbine (*ter*-bin), engine driven by the force of a liquid or a gas on curved blades fastened so as to form a rotating wheel.

Umbra, dark part of a shadow from which all direct light rays are cut off.

Unbalanced pressure, pressure not balanced by an equal amount of pressure in the opposite direction.

Vacuoles, large area inside a cell filled with cell sap.

Vacuum, a space which is empty of all matter.

Vacuum tube, tube from which most or all air has been removed.

Vegetative reproduction, plant reproduction other than by seeds.

Vibration, repeated motions.

Virtual image, one which cannot be projected on a screen or a piece of paper.

Vitreous (*vit*-ree-us) **humor,** a thick liquid filling the space in the eyeballs.

Volatile, capable of moving rapidly from place to place or (of gases) from state to state.

Volcano, break in the earth's surface through which gas, melted rock, and dust flow out from the earth's interior.

Volt, unit of electrical pressure.

Voltmeter, instrument for measuring difference in voltage.

Volume, space occupied by an object or substance.

Warm front, a mass of warm air pushes into a colder air mass.

Water displacement, usually the volume or the weight of the water pushed aside by a body floating in it or submerged in it.

Waterspout, tornado at sea.

Water table, level of the soil water.

Water turbine, rotary motor propelled by the action of a current of water on a series of curved vanes.

Watt, power used when a current of one ampere is caused to flow by a pressure of one volt.

Wave frequency, number of complete waves or vibrations per second.

Wave length, distance from the middle of one sound wave to the middle of the next succeeding wave.

Weather, condition of the atmosphere at any one time and place.

Weathering of rocks, changing of rocks into soil by means of chemical and physical changes.

Weed, any plant growing in cultivated ground to the detriment of the crop or the disfigurement of the place.

Weight, measure of the earth's attraction for a body.

Welding, joining two pieces of metal together by the use of intense heat.

Wet cell, electrical cell using liquid materials.

Wind, air in motion.

Work, force exerted times the distance the force moves.

Wrought iron, practically pure iron, softer than steel and easily welded.

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